JOURNAL OF ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

MAY

1951

Volume 10 Number 2

EDITORIAL BOARD

L. E. Casida, *Editor and Chairman*

J. K. Loosli (1951)*
J. A. Whatley, Jr. (1951)
L. E. Kunkle (1952)
E. W. Crampton (1952)
E. P. Reineke (1953)
R. H. Burns (1953)
I. W. Rupel (1954)
Wise Burroughs (1954)

Ralph W. Phillips, *Editorial Adviser*
J. I. Miller, *Business Manager*

*Terms expire on December 31 of years indicated

OFFICERS OF THE SOCIETY

E. W. Crampton, *President*
H. M. Briggs, *Vice President*
J. I. Miller, *Secretary, Treasurer*
V. A. Rice, *North-Atlantic Vice President*
H. H. Leveck, *Southern Vice President*
C. E. Terrill, *Western Vice President*

Entered as second class matter under act of March 3, 1879, The Journal of Animal Science is published during February, May, August, and November by the Boyd Printing Company, Inc., 372–374 Broadway, Albany 7, N. Y. Domestic subscription price is $4.00 per year; rest of North and South America $4.50; all other places $5.00. Send your subscription to the publishers, 372–374 Broadway, Albany 7, New York or to J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y. Make check payable to the American Society of Animal Production. Foreign subscribers please remit by International money order or by a draft on a New York bank. Notices of change of address should be in the hands of Dr. Miller 40 days previous to month of issue, to insure prompt delivery. Missing copies, owing to change in address cannot be supplied unless adequate notice has been given. Subscribers or members failing to receive a number of the Journal should notify the Business Manager within 90 days of publishing date. Missing copies will be replaced only if due to error on the part of the Business Manager or printing company.

JOURNAL OF

ANIMAL SCIENCE

Published Quarterly

by the

American Society of Animal Production

MAY

1951

Volume 10 Number 2

CONTENTS

	Page
The impact of genetics on animal breeding. Jay L. Lush	311
A comparison of the effects of aureomycin, penicillin and streptomycin upon spermatozoan livability and control of bacteria in bovine semen. R. M. Myers and J. O. Almquist	322
Effect of vitamin B_{12} (A.P.F.) on the growth of calves weaned from milk at an early age. L. L. Rusoff and M. O. Haq	331
Distribution of P^{32} in the tissues of a steer fed grass from land that received labeled fertilizer. R. L. Shirley, G. K. Davis and J. R. Neller	335
Significance of the differences in digestibility of feeds by cattle and sheep. M. A. Cipolloni, B. H. Schneider, H. L. Lucas, and H. M. Pavlech	337
The use of digestible energy in the evaluation of feeds. G. P. Lofgreen	344
Relations between some body measurements and certain performance characters in Milking Shorthorn steers. M. L. Kohli, A. C. Cook and W. M. Dawson	352
Genetic and environmental correlations between weaning scores and subsequent gains in the feed lot with record of performance steers. B. Knapp, Jr. and R. T. Clark	365
Correction factors for adjusting weaning weights of range calves to the constant age of 190 days. L. E. Johnson and C. A. Dinkel	371
A study of classification scores of Hereford cows. W. Gifford, C. J. Brown and M. L. Ray	378
Relationships of five body measurements to slaughter grade, carcass grade, and dressing percentage in Milking Shorthorn steers. A. C. Cook, M. L. Kohli and W. M. Dawson	386
Moisture, ash, and fat content of connective tissue from cattle of different ages. R. W. Bray, P. H. Phillips and G. Bohstedt	394
A study of meat characteristics of Karakul sheep. O. G. Hankins, R. L. Hiner and V. L. Simmons	399
Effects of corpora lutea removal and replacement with progesterone on pregnancy in goats. J. Meites, H. D. Webster, F. W. Young, F. Thorp, Jr., and R. N. Hatch	411
A permanent rumen fistula cannula for cows and sheep. G. E. Stoddard, N. N. Allen, W. H. Hale, A. L. Pope, D. K. Sorensen and W. R. Winchester	417
The effect of the corn-alfalfa hay ratio on the digestibility of the different nutrients by sheep. C. A. Phillips, S. D. Hardin, and W. E. Thomas	424
Cobalt metabolism studies with sheep. H. A. Keener, R. R. Baldwin and G. P. Percival	428
The effect of alfalfa ash upon roughage digestion in sheep. R. W. Swift, R. L. Cowan, G. P. Barron, K. H. Maddy and E. C. Grose	434
The effect of methionine supplementation upon the utilization of pea and alfalfa proteins by sheep. E. W. Klosterman, D. W. Bolin, E. L. Lasley and W. E. Dinusson	439
Effect of stage of maturity and storage on quality, quantity, and nutritive value of South Dakota prairie hays. G. E. Staples, R. M. Jordan, G. F. Gastler, A. B. Nelson and C. J. Franzke	447
Genetic and environmental factors affecting type and condition in Navajo and Navajo crossbred weanling lambs. G. M. Sidwell, D. A. Price and J. O. Grandstaff	455
A study of crossbreeding sheep. K. P. Miller and D. L. Dailey	462
Changes in the hormone content of swine pituitaries during the estrual cycle. G. E. Robinson, Jr. and A. V. Nalbandov	469
Variation in puberty phenomena in inbred gilts. A. C. Warnick, E. L. Wiggins, L. E. Casida, R. H. Grummer and A. B. Chapman	479
Variation in puberty phenomena in inbred boars. E. L. Wiggins, A. C. Warnick, R. H. Grummer, L. E. Casida and A. B. Chapman	494
Heterosis in crosses of inbred lines of Duroc swine. D. Chambers and J. A. Whatley, Jr.	505
Inheritance of scrotal hernia in swine. W. T. Magee	516
The effect of summer environment on the body temperature and respiration rate of swine. A. L. Tidwell and J. L. Fletcher	523
Seasonal variation in the fat, vitamin A and vitamin D content of sow's colostrum and milk. J. P. Bowland, R. H. Grummer, P. H. Phillips and G. Bohstedt	533
The growth promoting effects of various antibiotics on pigs. R. W. Luecke, J. Thorp, Jr., H. W. Newland and W. N. McMillen	538
The effect of soft and hard coal on the growth rate of pigs. R. H. Grummer, J. H. Meyer and G. Bohstedt	543
Value of corozo palm nut and sesame oil meal, bananas, A.P.F. and cow manure in rations for growing and fattening pigs. R. L. Scobb and E. Salazar	545
Relative value of vitamin A and carotene for supplying the vitamin A requirements of swine during gestation and beginning lactation. D. B. Parrish, C. E. Aubel, J. S. Hughes and J. D. Wheat	551
News and Notes	560

Contents of previous issues of the Journal of Animal Science are indexed in the Agricultural Index which is available in libraries and in the November issue of each complete volume of the Journal.

THE IMPACT OF GENETICS ON ANIMAL BREEDING

JAY L. LUSH
Iowa State College[1]

IF we would know how genetic knowledge is changing animal breeding practices or is likely soon to change them, we can probably get our best clues by asking what the animal breeders are studying now. Predictions made on this basis will not be wholly accurate, of course. The "endless frontier" nature of science precludes high accuracy in any method of predicting the future, especially the distant future. Yet always there is some time-lag in applying newly won knowledge to the arts and business of production. Predictions of the immediate future on the basis of that time-lag are likely to be a bit better than guesses.

Genuinely new knowledge and developments are more likely to be found where several investigators are delving, more or less independently, in a field than by lucky chance or sudden inspiration descending on a stray worker who is thinking of something else. To be sure, the latter does happen, even if but rarely, and its consequences are sometimes tremendously important. Saul was out looking for his father's asses when he found a kingdom! Predicting the future by studying current research is a bit like watching a river at a given point and predicting its downstream course. Usually we can see a few hundred yards with practical certainty. Often by looking at the hills on the horizon we can make a fair estimate of its general course for several miles. But we are almost certain to be wrong if we predict that it will continue indefinitely in that direction for hundreds of miles.

The first half century of genetics, dating that from the rediscovery of Mendel's laws, is described in a forthcoming book[2] which includes many details about the impact genetics has already had on animal breeding, as well as on plant breeding and on man's ideas about biology and about himself. It would be wasteful to repeat those here in detail, but a few will provide background for what follows.

In genetics itself, the first twenty years were devoted largely to testing whether Mendel's laws were true, whether they applied to all characters or only to certain kinds such as colors and superficial details of form,

[1] Journal Paper No. J-1872 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 1127. An invitation paper presented before the Breeding and Genetics Section of the American Society of Animal Production Meeting, 1950.

[2] Genetics in the 20th Century. Macmillan. 1951.

whether the gene really did remain constant or was changed a bit by its long and intimate association in the heterozygote with its slightly different allele, identifying the chromosomes as the physical carriers of the genes, and exploring the relation of gene differences to environmental differences in causing the characters we actually observe. The consequences of various mating systems and the genetics of populations, although studied a bit in the first two decades, developed mainly in the third and fourth decades out of the need to understand the results of inbreeding and selection experiments, plus a growing realization that the genes were too many and their effects and interactions were too varied to permit ever knowing the complete Mendelian formulas of any individuals. The physiology and chemistry of the processes by which the genes do their work is only beginning to be clarified even now.

Genetics first affected animal breeding by explaining the reasons for many facts which the breeders already knew and by removing much of the mystery. Mendel's laws of segregation and recombination, and the sampling nature of inheritance which they automatically cause, explained atavism, reversion, the inconsistent importance of different ancestors in individual cases, why full brothers were not exactly alike in heredity, and many other puzzling things which had seemed irregular or contradictory. Many superstitions, such as telegony and that maternal impressions would affect the young, began to melt away as it was seen that the supposed evidence for them could be explained more consistently in other ways. The psychological effect of having the mystery dispelled from animal breeding and knowing that one was struggling only to utilize natural laws, rather than against capricious, unknown and possibly hostile forces, must have been considerable although no way to measure it is apparent.

Breeders, fully convinced of the importance of heredity and that pedigrees were useful, but baffled in all attempts to predict individuals perfectly from their pedigrees, had supposed that a large flood of new heredity, . . . mutations we would now say, . . . was pouring into the population at all times. They had found no other plausible explanation for the unlikeness of full brothers and for the fact that populations continued variable in spite of the supposed blending nature of inheritance, which they thought would "swamp" individual variations. They spent much time and effort in trying to find some way of evaluating pedigrees perfectly and of controlling in their favor the causes of the supposed large amount of mutation. Mendel's laws made it obvious that no system of evaluating pedigrees ever could be perfectly accurate in its prediction of individuals, as long as either parent was heterozygous

for any genes. Pedigrees began to be seen in their proper light as rough guides, . . . certainly worth at least a lick and a promise, . . . but incapable of being made to yield perfectly accurate predictions of individual offspring.

As it became clearer that mutations are too rare to be of much practical importance within the short space of time which interests the plant and animal breeder, efforts at controlling their number or direction by supplying a particular kind of feed or care or climate diminished. The resources thus released became available for useful purposes. To be sure, keeping animals under special conditions will sometimes be worth doing because it makes them show more clearly the genetic differences between them, and thus permits selections to be more accurate. We still shrink from following this policy to its logical limits such as, for instance, exposing our animals deliberately to disease in order to find which ones have natural resistance.

Breeders had long known that an animal is likely to transmit as if it were somewhere between its own characteristics and those of its close relatives. The controversy during the middle of the 19th century among breeders in the German-speaking lands about the doctrine of "racial constancy" is an extreme example of that. Galton, in his attempts to describe the facts of inheritance quantitatively, had named this tendency for individuals to be between their parents and the racial average, "regression," and he referred to it as "the pull of the race." Many supposed it to prove that breeders were "going against nature" in trying to improve their animals by selection and therefore could go only a little way in this direction. It is now understood that this tendency for extreme parents to have offspring nearer the average of the race is little except the automatic consequence of the non-inheritance of environmentally caused variations. Also, where only one parent is considered at a time, the other parent is likely to be nearly a random individual of the race unless mating was far from random. Also some of the variations in the parent may not be transmitted because they were effects which genes cause only in certain combinations or in special environments not repeated for the offspring.

The early enthusiasts about Mendelism could see little relation between that and the findings of the biometricians who worked with Galton's methods. Some even supposed these to be in conflict. But almost as soon as the geneticists began to work with characters affected by three or more pairs of genes, and especially if those characters were strongly affected by uncontrolled environmental variations, it became clear that there was no real conflict but only some superficial differences

which came automatically because one group studied the complex result of many ingredients while the other group studied those ingredients one by one. Except for its algebraic language the biometrical approach, as subsequently modified and expanded into population genetics, is more nearly the way animal breeders usually see their problems, since the individual animal's economic usefulness or net merit is affected by more genes than can be catalogued and by many known and unknown environmental circumstances besides.

Some of the main changes in animal breeding practices between 1900 and 1950 are the following: Much more effort to measure impartially the merit of individuals . . . as in cow testing, trapnesting, type classification, and pig testing stations, . . . wider and more systematic use of progeny tests and sib tests, artificial insemination in dairy cattle for economic reasons and also as a way to intensify the selection of dairy bulls, more effort at standardizing the environment under which individual merit is measured or correcting for such environment as was not standard, and a bit more use of special mating systems like inbreeding. Distant ancestors and characters which are only breed trademarks are now emphasized less, although they still receive too much attention and thus reduce the intensity of selection for important things. The importance of non-selectivity in the data, if they are to be unbiased, is understood as concerns progeny tests and sib tests, although many do not yet see that it is equally important to judge the individual animal by the average of all its records or appraisals. Breed registry societies are spending much more of their resources in measuring individual merit and in promoting progeny tests than they did a half century ago. Production records and sometimes linebreeding count for more in the auction ring. The show ring remains a place to exalt and teach a visible ideal, rather than to appraise the probable breeding merit of any noticeable fraction of a breed. Attempts to make the awards jointly on type and production have hardly been successful, although perhaps not all of the plausible devices for doing this have yet been tried. Even the produce-of-dam and get-of-sire classes have not had much genetic effect because it seems impossible under show conditions to achieve enough non-selectivity of the offspring to give such a progeny test some useful meaning. I see no way to estimate how many of these changes would have come anyhow, even if genetics had not developed. Some, such as appreciating the importance of non-selectivity in the progeny test, would hardly have come without experience in analyzing Mendelian ratios.

The average productivity of livestock has increased markedly and rather steadily. The Bureau of Agricultural Economics estimates[3] that the production per animal unit in the United States has increased more than 45 percent in the 29 years from 1919 and 1920 to 1948 and 1949. I see no valid way to measure how much of this came from improved feeding, from improved sanitation or other health measures, and how much from genetic improvement, but the latter must have been considerable.

Agricultural college herds had little *direct* effect in changing the genetic composition of the breeds. College-bred ancestors are rare in the pedigrees of random samples of the breed. The major reasons appear to be two. First is the difficulty or inappropriateness of the colleges pushing their sales of breeding stock as vigorously as seems necessary to make a herd a center from which sires go to be used in the leading seedstock herds of the breed. Second is the usual timidity or conservativeness of the men in charge of the college herds. Most of these are teachers or demonstrators, as well as research workers and breeders, and are naturally reluctant to do risky things with the public property in their charge. It is somewhat hazardous for the teacher or demonstrator to be found wrong. Certainly this detracts from his self-esteem! The research worker expects to be wrong often in his preliminary estimates although he, too, tends to be conservative in his conclusions. He rightly requires much higher odds in favor of his published conclusions than the business man can afford to require for most of his decisions.

At any rate, when the man in charge of a college herd needs a new sire he usually goes among other herds on a quest for an ideal sire, somewhat as Jason went seeking the Golden Fleece, . . . and with about as much prospect of success! If the calves in the college herd do not satisfy him, he is not seriously deterred by the fact that their sire is one which he or his predecessor selected by the same methods he proposes to try again. He appears not to ask himself what real reason there is for thinking he will be any more successful this time. Not long ago George Odlum expressed this pithily concerning a proposal that Britain import more Friesians from Holland, when he said in effect: We have imported several times before and have bred these cattle pure. If now the cattle in Holland are really better than ours, then either we did not get in the earlier importations animals equal to their best or they are better breeders than we. If the former is true, what reason is

[3] The Agricultural Situation. May, 1950. Page 3.

there to think we will do better this time? If the latter is true, we should import some Hollanders, rather than more of their cattle!

If the calves in the college herd do satisfy the man in charge, he is reluctant to use one of his own bull calves as a sire lest the inbreeding (which would usually be less intense than he thinks) might damage the herd so that he would be ashamed of it before his students and visitors. Aside from the public relations aspects of the matter, why should he not damage the herd, . . . if thereby he learns something? Most of the genes in the college herds, whether good or bad, are going to pass out of the breed anyhow, because nearly all the breeding stock sold will go to grade herds or to purebred herds just being founded. For our own education on this point there is room for more studies of what actually does happen in college herds. One might take an inventory list of the registered animals in the herd in 1900, or some other date several animal generations in the past, and trace just what did happen to their descendants. Or he might list those in the herd now and figure what small fraction of their genes probably came from animals which were in the herd even as recently as 15 or 20 years ago.

The colleges may have had an incalculably great influence on breed improvement by spreading knowledge of good breeding practices through their demonstration herds and by teaching their students, on and off campus. Certainly the college staffs played a large part in promoting production testing and in spreading the ideas of the show-ring.

The problems currently interesting to research workers in animal breeding have come largely from their having tried various plausible breeding plans in actual operation in recent years. The conferences and projects of men working in the regional swine and sheep breeding laboratories and, more recently, in the dairy cattle, beef cattle, and poultry breeding laboratories have had much to do with this. The partly parallel experience of the corn breeders also has had strong influence. In many ways corn breeding problems are more like animal breeding problems than they are like the problems of breeding naturally selfed plant species, such as oats, soy beans and wheat.

The genetic information most needed now for making rapid progress in animal breeding hinges around four questions or fields. 1. How to make selection more effective. This means making more useful selection indexes. 2. Are the non-linear interactions between heredity and environment important? 3. How important really is epistasis? 4. Is overdominance important enough to need attention?

Also, as we quantize our breeding plans further, we need to know the vital statistics of farm animals more accurately. How intense *can*

our selection be? What will happen to the generation interval if we rely on the sib test more and on the progeny test correspondingly less? What rate of genetic improvement can reasonably be expected? How much could this be changed by the maximum practical use of artificial insemination? How much by transfer of fertilized ova, if that ever becomes feasible in practice? To know the answers to such questions and thus to make our plans sounder, we need to know more about the means and likely variations in such things as expectation of life, replacement rates, percentage calf and lamb crops which can reasonably be expected, generation intervals, and how much each of these can be changed by any changes in our management which are economically possible. We are beginning to be able to compare the probable results with the probable costs of a proposed change in breeding procedure, although as yet only within wide limits.

To make sound selection indexes requires four kinds of information: The heritabilities and economic values of the various traits we would consider, and their genetic and phenotypic correlations with each other.

Economic values are just another way of saying that defining the ideal is the first step in making a breeding program. The ideal is likely to change at least a little, as prices and other economic conditions do; yet the breeder cannot afford to shift his ideals that rapidly back and forth. Hence some compromise may be necessary.

Knowledge of heritabilities is increasing rapidly, although the confidence intervals for those are still uncomfortably wide in most cases. The idea of heritability is an old one, going at least as far back as Galton's time. Davenport in 1907 even expressed it quantitatively in what he called the "coefficient of heredity". However, in the state of genetic knowledge then they could not appreciate fully the pitfalls in assuming, as their operations did, that the correlations between relatives were caused wholly by genic likeness, and in neglecting the breeding structure of the population.

Phenotypic correlations between two traits in the same individual were widely investigated during the first three decades of genetics, but as yet we know only a little about the genetic correlations. The methods for estimating those have wide sampling errors. In cases, if there be such, where selection has been practiced for a long time and is now almost or completely ineffective, yet heritability seems high, there is *a priori* reason to suspect that strongly negative genetic correlations exist. This causes us to undo, when selecting for character X, what we did when we selected for character Y, and vice versa. In the limiting case where this negative genetic correlation is perfect, this becomes the

same thing as overdominance if the desirable phases of both X and Y are at least partially dominant. Probably in many more cases the genetic correlation is negative but imperfect. Then efficient selection indexes are likely to contain surprising changes in emphasis or even reversals from what we would think if we consider only the economic values. If we have the information necessary for constructing selection indexes, we can predict fairly well the average *rate* of improvement per year or per generation over the next few generations, although we are powerless to predict the ultimate genetic *limits* to such improvement.

By interactions between environment and heredity we mean merely that the phenotypic difference between genotype A and genotype B is not the same in environment X as it is in environment Y. We know that such things do exist, at least to a mild degree, between breeds. Some breeds are better adapted than others to warm climates, to lowlands, or to heavy feeding, or to early marketing, but under the reverse conditions the adaptability of certain breeds may also be reversed. Do such differences exist between individuals within breeds to such an important extent that we need to take account of this in our breeding plans? Some of the observations on identical twins in cattle suggest that they do, but that evidence can still be interpreted in other ways. If these interactions really are important, they indicate that we should have a separate breed for every kind of environment which is extensive enough to warrant such an enterprise. Or can we solve it by selecting for versatility itself as a primary characteristic which is highly important? In any event, the question of the kind of environment under which to keep the animals whose merit is to be measured becomes much more important than if the effects of variations in environment and in heredity are merely added to each other.

Epistasis surely must be important in differences between major groups, such as between species or even between distinct types within a species. That seems to follow from the rather large differences between parts or organs in such cases and the obvious importance of having these balanced with each other so that the animal as a whole is an efficiently functioning unit. But it is not so certain that epistasis is important enough in the differences between individuals within the same breed that we need to take it into account as a major factor in shaping our breeding plans. If it is that important, we need to make much use of the linebreeding form of inbreeding and selection—emphasis should be more on the family and less on the individual than if epistasis were unimportant. Highest hopes for future progress would be on the individuals which segregate out of the best crosses between

partially inbred lines which themselves average only moderately high in merit.

We know still less about the importance of overdominance. If it is common, that would explain many things which otherwise appear puzzling, such as the prevalence of heterosis and of polymorphism and some cases where selection seems ineffective although genetic variability remains. Even if only a few loci are overdominant, still those could furnish a large share of the genetic variance remaining in a population which has long been under steady selection. The most efficient breeding plans to utilize overdominance will take the form of making and maintaining relatively pure seedstocks which individually are lower in merit than the best crosses which can be made from them. These will be intercrossed to produce the commercial or market stock. The present hybrid corn plan is of this sort. It seems adaptable to chickens with few modifications. For less prolific animals the most feasible plan of this kind seems to be some form of rotational crossbreeding.

The early work with hybrid corn used the blunderbuss method of making many inbred lines and then testing in crosses whatever lines happened to result. If much of the success of hybrid corn is due to overdominance, instead of merely to eliminating undesirable recessive genes as many of us at first supposed, then it appears possible by recurrent selection or recurrent reciprocal selection to make lines superior to any yet found. In this way one could systematically build the lines so that they would fit each other, as a key fits a lock, to produce crosses with the maximum heterozygosis in loci which are overdominant and yet be homozygous for the better gene in most of the loci in which overdominance does not occur. Doing this might not even require inbreeding. Most of these ideas are new enough that we are almost certain to be partly wrong in our understanding of them. The experimenting to remedy that will mostly be done with corn and suitable laboratory organisms but it doesn't seem too early to start some tentative explorations even with cattle and pigs.

If the breeder is contending only with partial or complete dominance, with epistasis, with environmental confusion, or even with interactions between environment and heredity, or any mixture of these, his ultimate goal remains to make a purebreeding strain as good as or better than any cross which can be made. This is what most of us have had in mind from time immemorial when we thought of breeding goals. But if overdominance really is important, this outlook will change radically. The more important overdominance is, the more we should judge the individual's breeding worth by its offspring from some specific cross and

the less by its own qualities or by its offspring from mates in its own line or strain. The contrast is perhaps greatest in what we would do when we find two lines which cross well. If we think the excellence of the cross is due to epistasis, we will try to make better lines from among the segregates from that cross. But if we knew the excellence of the cross was due to overdominance, we would resolutely avoid using animals of that cross for breeding purposes. Instead, in seeking lines which would cross still better with line X, we would try to find them by crossing lines which all do better than average with X but do not cross especially well with each other. Then by interbreeding these somewhat mediocre crosses we would try to make new lines which would cross with X still better than any lines we yet have.

In recent years the corn breeding literature has contained much about "general" and "specific" combining ability. These are operational definitions and pertain to the population on which they are measured. Differences in general combining ability mean that one line averages better than another when both are crossed on other lines in that group. Differences in specific combining ability exist when a line does better or worse in a cross with one of these lines than one would expect from the way it behaves in crosses with the other lines.

Genetic improvement in general combining ability is to be sought by selection, perhaps with more use of progeny tests and sib tests and more careful standardizing or correcting of environment and more use of selection indexes than is traditional. Under those circumstances inbreeding is used mainly to build a line around an individual or to hold a line together until the real breeding value of that individual or line is known accurately enough to decide whether to discard it or to use it widely or moderately.

So far as differences in specific combining ability are due to partial or complete dominance or to epistasis, genetic improvement is sought by the same methods, but with more use of inbreeding to identify the breeding values of individuals and lines and, in the case of epistasis, to keep the good combinations together. Special tester strains begin to have some use, as homozygous recessives are useful to test for heterozygosis when dominance is complete and especially weak strains are useful for finding which lines have the larger factors of safety when epistasis is of the threshold or ceiling kind. But when specific ability is due to overdominance, choice of the tester strain, . . . and building still better ones, . . . becomes of paramount importance. *The cross* becomes

the center of attention, not only for commercial production but also for judging the parents.

If some one can devise a way to measure the effects of overdominance separately from other causes of specific combining ability, a long step forward in breeding plans will be possible. Unfortunately the tests available so far are not adapted to organisms which cannot be selfed. They are not very sensitive even for those. It remains possible that overdominance is unimportantly rare after all and that we are much too excited about it. Perhaps not!

A COMPARISON OF THE EFFECTS OF AUREOMYCIN, PENICILLIN AND STREPTOMYCIN UPON SPERMATOZOAN LIVABILITY AND CONTROL OF BACTERIA IN BOVINE SEMEN[1, 2]

R. M. MYERS[3] AND J. O. ALMQUIST[5]

Pennsylvania Agricultural Experiment Station[4]

AT the present time the use of antibiotics appears to offer the most efficient means of controlling bacterial growth in bovine semen used for artificial breeding. Earlier studies at this Experiment Station (Almquist *et al.*, 1948, 1948a) have shown that either penicillin or streptomycin would inhibit the growth of bacteria without exerting harmful effects upon the survival of bull spermatozoa. Most effective bacterial control, however, was achieved only when the combination of penicillin plus streptomycin was employed (Almquist *et al.*, 1949).

Recently workers in this field have focused attention on some of the newly developed antibiotics, including aureomycin, polymyxin and chloromycetin. Reports by Myers *et al.* (1950) and Sykes and Mixner (1950) and the recent paper by Foote and Bratton (1950) indicate that aureomycin inhibits bacterial growth but is relatively toxic to the motility of bull spermatozoa. Polymyxin (Foote and Bratton, 1950) and chloromycetin (Sykes and Mixner, 1950) seem to be less harmful to the spermatozoa and the former antibiotic was found to be highly bactericidal. No data concerning the effect of chloromycetin on the multiplication of bacteria in bull semen or of the stability of any of the three antibiotics in stored semen have been reported.

Aureomycin has been found to possess bacteriostatic and/or bactericidal activity against both gram-positive and gram-negative organisms (Paine *et al.*, 1948, 1948a; Price *et al.*, 1948). A number of the types of bacteria which it inhibits have been found in semen and are related

[1] Authorized for publication October 20, 1950, as paper No. 1629 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

[2] The data contained in this paper are part of a thesis submitted by the senior author to the Graduate School of The Pennsylvania State College in partial fulfillment of the requirements for the degree of Master of Science, June, 1950.

[3] Present address: Dept. of Animal Industry, North Carolina State College, Raleigh.

[4] Dairy Cattle Breeding Research Center.

[5] The authors wish to express their appreciation to Miss Esther Martin of the Department of Bacteriology for conducting the aureomycin assays. The aueromycin hydrochloride used in these studies was provided by Lederle Laboratories Division, American Cyanamid Company, Pearl River, New York, and the penicillin and streptomycin were supplied by Charles Pfizer and Company, Inc., Brooklyn, New York.

to breeding problems. Because of its wide antibacterial activity it is possible that use of aureomycin in diluted bull semen might obviate the need for both penicillin and streptomycin in obtaining efficient control of bacterial growth.

The present paper deals with the effect of aureomycin upon spermatozoan livability and the control of bacterial growth in diluted bovine semen, including a comparison of its effects with those of penicillin and streptomycin. Data on the stability of aureomycin in stored semen also are presented.

Experimental

In the following investigations aureomycin hydrochloride with sodium glycinate buffer, the sodium salt of penicillin G and streptomycin sulfate were used. Three lots of aureomycin are represented. The diluter was composed of equal parts of fresh egg yolk and 2.9 percent sodium citrate dihydrate. The diluted semen was stored at 4.5° C. and motility estimations were made every 2 days for a 14-day period.

Effect of aureomycin upon the livability of spermatozoa

A preliminary study involving eight samples of semen was conducted to obtain a general idea of the relative toxicity of aureomycin to spermatozoan survival. A dilution rate of one part of semen to 20 parts of yolk-citrate diluter was used and aureomycin hydrochloride was added at levels of 12.5, 25, 50, 100, 250, 500 and 1,000 μg. per ml. of diluted semen. Diluted semen containing no aureomycin served as the control. Concentrations of 12.5 and 25 μg. per ml. did not appear to be harmful to any great extent, while the 50 μg. level showed some injurious effect upon sperm motility during the latter half of the 14-day storage period. Levels above 50 μg. brought about definite spermicidal action and the 500 and 1,000 μg. levels produced a rapid and large decrease in spermatozoan survival.

Based on the preliminary findings, an experiment was designed in which aureomycin hydrochloride was added to 24 ejaculates at the rate of 50, 100, 250, 500, 750 and 1,000 μg. per ml. of diluted semen. To compare the relative toxicity of aureomycin with antibiotics previously studied in this laboratory, the following three treatments also were included: (a) 1,000 units per ml. of penicillin, (b) 1,000 units or μg. per ml. of streptomycin and (c) 1,000 units of each per ml. of diluted semen. A rate of dilution of one part of semen to 64 parts of yolk-citrate diluter was employed. The 12.5 and 25 μg. levels of aureo-

mycin were not included since the preliminary study showed that these levels did not control bacterial growth efficiently. Aureomycin levels as high as 1,000 μg. per ml. were included so that this concentration could be compared to the above amounts of penicillin and streptomycin.

The 24 ejaculates had a mean concentration of 1,230,000 spermatozoa per cubic mm. and a mean initial motility of 64 percent active spermatozoa.

Table 1 gives the mean motility data for the 24 ejaculates. Analysis of variance showed that all levels of aureomycin studied (50 to 1,000

TABLE 1. THE EFFECT OF AUREOMYCIN UPON THE LIVABILITY OF BULL SPERMATOZOA

(Av. of 24 ejaculates)

Aureomycin μg. per ml. diluted semen	Percent of motile spermatozoa							
	Before storage	After storage at 4.5° C. for						
		2 days	4 days	6 days	8 days	10 days	12 days	14 days
Control	64	57	47	38	24	17	9	1
50	64	53	44	29	16	8	4	2
100	64	52	39	25	8	4	2	1
250	64	54	30	16	4	1	1	0
500	64	49	20	10	2	1	0	
750	64	46	17	6	0			
1000	64	42	15	5	0			

μg. per ml.) brought about a highly significant decrease in spermatozoan livability during the 14-day storage period as compared to semen containing no aureomycin. A sharp decrease in motility was noted as early as the fourth day of storage, particularly in levels of 250 μg. per ml. and over.

The relative toxicities of aureomycin, penicillin and streptomycin, as well as of a combination of penicillin and streptomycin, are shown in table 2. Aureomycin brought about a highly significant decrease in spermatozoan livability as compared to the control samples or to those containing penicillin and/or streptomycin. Penicillin and streptomycin, alone or in combination, maintained motility which was equally as good as that shown by the untreated controls.

Since diluted semen seldom is used after 4 days of age in routine artificial breeding, it was believed that the lower levels of aureomycin might not be injurious to spermatozoan motility during a relatively short storage period. Thus an analysis of variance was made which

included only the motility data for 2 and 4 days of storage. Mean differences between the 50 μg. level of aureomycin and 1,000 units of penicillin, 1,000 μg. of streptomycin or both penicillin and streptomycin were not significant statistically during 4 days of storage although they were significant when based on 14 days of storage. The difference between untreated semen and semen containing 50 μg. of aureomycin was significant at the 5 percent level rather than at the 1 per cent level as previously noted.

TABLE 2. COMPARATIVE TOXICITIES OF AUREOMYCIN, PENICILLIN AND STREPTOMYCIN UPON THE LIVABILITY OF BULL SPERMATOZOA
(Av. of 24 ejaculates)

	Percent of motile spermatozoa							
	Before	After storage at 4.5° C. for						
Treatment	storage	2 days	4 days	6 days	8 days	10 days	12 days	14 days
Control	64	57	47	38	24	17	9	1
Aureomycin[1]	64	42	15	5	0			
Penicillin[2]	64	56	45	34	22	14	8	3
Streptomycin[1]	64	55	45	31	18	13	8	4
Penicillin plus streptomycin[3]	64	55	48	38	20	13	8	3

[1] 1,000 μg. per ml.
[2] 1,000 units per ml.
[3] 1,000 units penicillin + 1,000 μg. streptomycin per ml.

Effect of aureomycin upon bacterial growth

Plate counts were determined on undiluted semen and diluted semen with and without antibiotics after storage for 0, 4, 8 and 16 days at 4.5° C. Veal infusion agar containing 4 percent defibrinated bovine blood was used for determining the approximate numbers of living bacteria. Control plates for sterility tests of yolk-citrate diluter, plating media and glassware employed also were made. All plates were incubated for 96 hours at 37° C.

Due to the fact that molds appeared on the blood agar plates cultured from six of the 24 semen samples studied, only 18 ejaculates were acceptable for determining the effect of aureomycin upon bacterial growth. Bacterial plate counts for the 18 freshly collected semen samples showed considerable variation. The average total count was 85,000 bacteria per ml., with a range of from 3,400 to over 300,000 per ml. Three ejaculates had total counts of less than 10,000 bacteria per ml. while five had counts of over 100,000 per ml.

The effect of aureomycin upon bacterial growth is shown in table 3. The numbers of bacteria per ml. are expressed as arithmetic means. All levels of aureomycin (50 to 1,000 μg. per ml.) inhibited bacterial growth when compared to diluted semen containing no antibiotic. The

TABLE 3. THE EFFECT OF AUREOMYCIN UPON BACTERIAL GROWTH IN DILUTED SEMEN STORED AT 4.5° C.
(Av. of 18 ejaculates)

Aureomycin μg. per ml. diluted semen	Numbers of bacteria per ml.			
	Before storage	After storage for		
		4 days	8 days	16 days
Control	41,000	39,000	85,000	160,000
50	3,500	3,300	1,300	7,200
100	340	150	300	490
250	100	90	70	400
500	100	60	60	300
750	60	220	30	270
1000	70	30	50	230

TABLE 4. COMPARATIVE EFFECTS OF AUREOMYCIN, PENICILLIN AND STREPTOMYCIN UPON BACTERIAL GROWTH IN DILUTED BULL SEMEN STORED AT 4.5° C.
(Av. of 18 ejaculates)

Treatment	Numbers of bacteria per ml.			
	Before storage	After storage for		
		4 days	8 days	16 days
Control	41,000	39,000	85,000	160,000
Aureomycin[1]	70	30	50	230
Penicillin[2]	310	460	150	770
Streptomycin[1]	60	40	50	610
Penicillin plus streptomycin[3]	200	70	120	580

[1] 1,000 μg. per ml.
[2] 1,000 units per ml.
[3] 1,000 units penicillin + 1,000 μg. streptomycin per ml.

50 μg. level, however, was less efficient than higher concentrations. Apparently there was little difference in the degree of bacterial control exerted by the 100 μg. to the 1,000 μg. levels since the numbers of bacteria per ml. at these levels were very similar.

Table 4 shows the comparative effects of aureomycin, penicillin and streptomycin upon bacterial growth in stored diluted semen. The data in this table show that the degree of bacterial control exhibited by the

addition of 1,000 μg. of aureomycin compared favorably with the addition of either 1,000 units of penicillin, 1,000 μg. of streptomycin or the combination of penicillin plus streptomycin.

A comparison of the data in tables 3 and 4 reveals that aureomycin levels of from 100 μg. to 1,000 μg. per ml. of diluted semen were equally as effective for controlling bacterial growth as the levels of penicillin, streptomycin and penicillin plus streptomycin employed.

Stability of aureomycin in diluted semen

A preliminary study showed that there was no appreciable loss of aureomycin activity in diluted semen after storage for 0, 4, 8 and 24

TABLE 5. THE STABILITY OF AUREOMYCIN IN DILUTED BULL SEMEN STORED AT 4.5° C.
(Av. of 18 determinations)

Theoretical μg. of aureomycin	Aureomycin by assay (μg. per ml. diluted semen)		
	Before storage	After storage for	
		8 days	16 days
Control	0	0	0
50	64	59	54
100	134	123	111
250	346	305	276
500	686	610	567
750	1046	958	863
1000	1238	1115	998

hours and for 4 and 8 days at 4.5° C. On this basis, assays were made on 18 samples of diluted semen after 0, 8 and 16 days of storage. The cup plate method was employed for all assays, using a strain of *Bacillus subtilis* as the test organism.

The results of the assays are shown in table 5. Following storage for 8 days at 4.5° C. the loss in aureomycin activity averaged 10 percent for the six levels studied. After 16 days' storage the decline in concentration amounted to 18 percent of the initial amounts. In order to determine the effect of a higher storage temperature on the stability of aureomycin, seven tubes of diluted semen containing 500 μg. per ml. and six tubes containing 750 μg. per ml. were held at room temperature (approximately 22° C.) and assayed after 8 and 16 days. After 8 days the decrease in activity amounted to 50 percent while at 16 days the loss was 75 percent of the initial levels.

As indicated in table 5, the units of aureomycin obtained by assay of portions of the treated diluted semen always exceeded the theoretical

number of units added. Assays of the untreated control samples revealed no antibacterial activity.

Assays were not made on the diluted semen samples containing either penicillin or streptomycin, since their relatively high stability under storage conditions previously had been established by Almquist *et al.* (1948, 1948a).

Discussion

Sykes and Mixner (1950) found harmful effects upon spermatozoan motility when aureomycin was added at the rate of 125 to 250 μg. per ml. of diluted bull semen. Foote and Bratton (1950) stated that the dosage should not exceed 100 μg. per ml. of diluted semen to avoid spermicidal effects. The latter finding was based on a study involving 10 ejaculates stored for the relatively short period of 4 days as compared to the 14-day storage interval used in the present study. The relatively high toxicity of aureomycin found in our investigation is in general agreement with these reports except that the initial toxic level was somewhat lower. In the present study the addition of 50 μg. of aureomycin per ml. of diluted semen definitely was spermicidal over a 14-day storage period. Based on the maintenance of motility during the first 4 days of storage, however, the 50 μg. per ml. concentration of aureomycin was not significantly different from 1,000 units of penicillin per ml., 1,000 μg. of streptomycin per ml. or a combination of the two antibiotics. While this amount of aureomycin probably would not be harmful provided the semen was used for breeding purposes within 4 days, it should be noted that bacterial growth was not as effectively inhibited as at dosages of 100 μg. per ml. and above.

Aureomycin was effective in retarding the multiplication of bacteria in stored diluted semen and compared favorably in this respect to penicillin and streptomycin, used singly or in combination. It also was similar to penicillin and streptomycin with regard to its relatively high stability in stored semen. Undoubtedly the maintenance of high activity was aided greatly by the low storage temperature (4.5° C.) employed as well as by the presence of egg yolk in the diluter. This is based on the assay data which showed a much greater loss of activity when semen was stored at room temperature as compared to refrigerator temperature. The favorable influence attributed to egg yolk is taken from a recent report by Womack *et al.* (1949) which revealed that egg yolk contains a substance which inhibits the deterioration of aureomycin activity.

Present information indicates, therefore, that the use of aureomycin in routine artificial breeding probably will be limited by its spermicidal properties and that penicillin and streptomycin, alone or in combination, should be the antibiotics of choice for controlling the growth of bacteria in diluted bull semen. If added to semen used for breeding purposes within 4 days after collection the dosage of aureomycin should not be greater than 50 μg. per ml. of diluted semen.

Summary

Studies were conducted to determine the effects of aureomycin upon spermatozoan motility and bacterial control in bovine semen and to compare the results with those obtained using penicillin and streptomycin. Preliminary data from eight ejaculates showed that concentrations of 12.5 and 25 μg. per ml. of aureomycin did not affect the motility of spermatozoa but that higher levels were toxic. The 50 μg. per ml. level was toxic during the last half of the 14-day storage period. In the main experiment involving 24 semen samples, levels of aureomycin ranging from 50 to 1,000 μg. per ml. of diluted semen brought about highly significant decreases in spermatozoan livability during 14 days of storage as compared to semen containing no aureomycin. These levels of aureomycin inhibited bacterial growth except that the 50 μg. per ml. level was not as efficient as higher amounts. Aureomycin was relatively stable in diluted semen stored at 4.5° C. but lost much of its activity in semen stored at room temperature.

Penicillin, streptomycin and penicillin plus streptomycin were much less spermicidal than aureomycin. A concentration of aureomycin of 1,000 μg. per ml. was highly significantly more toxic to the spermatozoa than either 1,000 units of penicillin per ml., 1,000 μg. of streptomycin or a combination of 1,000 units of penicillin plus 1,000 μg. of streptomycin per ml. of diluted semen. Aureomycin compared favorably with the other antibiotics for the control of bacteria in diluted semen. Levels of from 100 to 1,000 μg. per ml. were about equally effective to the above mentioned amounts of penicillin and/or streptomycin.

Literature Cited

Almquist, J. O., P. J. Glantz and H. E. Shaffer. 1949. The effect of a combination of penicillin and streptomycin upon the livability and bacterial content of bovine semen. Jour. Dairy Sci. 32:183.

Almquist, J. O., P. J. Glantz and W. T. S. Thorp. 1948. The effect of streptomycin upon the livability and bacterial content of bovine semen. Jour. Dairy Sci. 31:501.

Almquist, J. O., W. T. S. Thorp and C. B. Knodt. 1948a. The effect of penicillin upon the livability, glycolysis, and bacterial content of bovine semen. Jour. Dairy Sci. 31:11.

Foote, R. H., and R. W. Bratton. 1950. Motility of spermatozoa and control of bacteria in bovine semen extenders containing sulfanilamide, polymyxin and aureomycin. Jour. Dairy Sci. 33:539.

Myers, R. M., J. O. Almquist and P. W. Prince. 1950. The influence of aureomycin upon the livability and bacterial content of bull semen. Jour. Dairy Sci. 33:394.

Paine, T. F., Jr., H. S. Collins and M. Finland. 1948. Bacteriologic studies on aureomycin. Jour. Bact. 56:489.

Paine, T. F., Jr., H. S. Collins and M. Finland. 1948a. Laboratory studies with aureomycin. Ann. New York Acad. Sci. 51:228.

Price, C. W., W. A. Randall and R. Welch. 1948. Bacteriological studies of aureomycin. Ann. New York Acad. Sci. 51:211.

Sykes, J. G., and J. P. Mixner. 1950. Bull semen toxicity of various saits, brands, and lots of penicillin, streptomycin, aureomycin and chloromycetin. Jour. Dairy Sci. 33:394.

Womack, C. R., E. H. Kass, E. B. Wells and M. Finland. 1949. A substance in egg yolk which inhibits deterioration of aureomycin activity. Proc. Soc. Exptl. Biol. and Med. 72:706.

EFFECT OF VITAMIN B_{12} (A.P.F.) ON THE GROWTH OF CALVES WEANED FROM MILK AT AN EARLY AGE[1, 2]

L. L. Rusoff and M. O. Haq
Louisiana Agricultural Experiment Station

VITAMIN B_{12} *per se* or animal protein factor containing B_{12} concentrate has been shown to have growth-promoting activity for poultry (Johnson, 1949; Richardson *et al.*, 1949) and swine (Catron and Culbertson, 1949; Catron and Wallace, 1949; Hogan and Anderson, 1949), and increased feed efficiency for these species. It is well known that cow manure (Whitson *et al.*, 1945; Rubin and Bird, 1946; Lillie *et al.*, 1949) and sheep feces (Abelson and Darby, 1949) are potent sources of the A.P.F. or vitamin B_{12} in growth-promoting activity for poultry. Ruminants probably obtain this factor either by rumen or intestinal symbiosis or from their ration. However, no research has been reported in the literature as to its growth-promoting effect on calves weaned from milk at an early age.

Johnson (1950) in a preliminary report stated that the calf requires vitamin B_{12}. According to Hartman, Dryden and Cary (1949), milk contains a growth-promoting factor—"Factor X"—which is related to vitamin B_{12}. Collins, Dietrich and Elvehjem (1950) have reported that cow's milk contains 2–3 μg. of vitamin B_{12} per liter. Thus, vitamin B_{12} is supplied by the diet of young calves since they consume milk or milk products during their first few weeks of life. After weaning from milk at a very early age it is possible that a vitamin B_{12} supplement may be necessary in the calf starter until the calf rumen has developed and is functioning normally so that rumen synthesis of vitamin B_{12} occurs.

This research was conducted to determine whether the addition of a vitamin B_{12} concentrate (A.P.F. No. 3) to an all-plant protein calf starter is of value in increased growth activity and increased feed efficiency when calves are weaned from milk at 28 days of age.

Experimental

Eighteen 3-day-old male calves were divided into two groups approximately equal in weight; each group consisted of 3 Holsteins and 6

[1] Presented in part before the American Dairy Science Association Annual Meeting, June 20, 1950, at Ithaca, N. Y.

[2] The data in this paper were taken in part from a Master's thesis submitted by M. O. Haq to the Graduate School of Louisiana State University, August, 1950.

Jerseys. The calves received colostrum for the first 3 days after birth and on the 4th day of age were placed in individual pens with wood shavings.

The calves were fed whole milk daily from cows of their own breed from a nipple pail at a rate of 1 lb. of milk for each 10 lb. of body weight up to 28 days of age. The calf starters were placed before the calves on the 4th day of age, and a medium-grade alfalfa hay was fed on the 7th day. These were fed free-choice throughout the experimental period to 90 days of age. After weaning from milk each calf

TABLE 1. COMPOSITION OF THE PLANT PROTEIN CALF STARTER

Ingredient	%	Vitamins[1]	gm/100 lb.
Cottonseed meal	35.0	Thiamine	0.10
Soybean meal	5.5	Riboflavin	0.25
Yellow corn meal	31.5	Ca-pantothenate	1.00
Rolled oats	15.0	Niacin	1.50
Wheat bran	10.0		
Bone meal	2.0		
Salt	1.0		
	100.0		

18.2 grams of A.P.F.[1] supplying 0.5 mg. of vitamin B_{12} per 100 lbs. was added to the starter for Group II.

[1] Supplied through the courtesy of Dr. D. F. Green of Merck and Co., Rahway, N. J.

was given approximately 120,000 I. U. of vitamin A (shark liver oil) daily. The calves were weighed weekly up to 90 days of age.

Group I received a basal plant-protein calf starter (table 1) while group II received the same ration supplemented with a vitamin B_{12} concentrate (Merck's A.P.F. No. 3[2]), which supplied 0.5 mg. of vitamin B_{12} per 100 lb. The calf starters contained 19.45% digestible protein, 72.02% T.D.N. and 5.52% crude fiber.

To verify any growth-promoting effect of A.P.F. No. 3 being specifically due to its vitamin B_{12} content, one Jersey calf, which was not included in any of the groups, received the basal plant protein ration plus weekly intra-muscular injections of 125 μg. of crystalline vitamin B_{12} after weaning from milk.

At 60 days of age, two Jersey calves in the A.P.F. group were given additional A.P.F. (2 gm.) daily by capsule to determine whether a higher level of the B_{12} concentrate might promote a greater growth response.

[2] Contained 12.5 mg. vitamin B_{12} per lb.

Results and Discussion

Table 2 shows the data concerning the average weights, heights, milk consumption and feed efficiency of the various groups of calves at 90 days of age.

Examination of table 2 shows that the average weight gains and increases in height of the calves on the basal plant-protein starter and those on the same basal starter supplemented with a vitamin B_{12} concentrate were very similar. No significant differences were found between the groups on statistical analysis of the data.

TABLE 2. AVERAGE WEIGHTS, HEIGHTS, MILK CONSUMPTION AND FEED EFFICIENCY OF CALVES AT 90 DAYS OF AGE

Group and ration	Number of animals	Total milk consumed	Average weights			lb. of starter per lb. of gain	Gain in height
			Birth	90 days	Daily gain		
		(lb.)	(lb.)	(lb.)	(lb.)		(in.)
	(Holsteins)						
Basal	3	241.5	94	192	1.09	2.41	5.4
Basal+A.P.F.	3	251.0	97	196	1.10	2.30	5.3
	(Jerseys)						
Basal	6	136.2	54	125	0.79	2.81	4.1
Basal+A.P.F.	6[1]	131.7	53	123	0.78	2.82	4.2
Basal+Crystalline B_{12} (1 mg. injected)	1	126.8	52	115	0.70	3.03	4.5

[1] Two of the animals received extra A.P.F. (55 μg. of vitamin B_{12} per day) beginning at 60 days of age.

The feeding of additional A.P.F. (55 μg. of vitamin B_{12} per calf per day) to the two calves in the A.P.F. group at 60 days of age for an additional 30 days and injections of crystalline vitamin B_{12} to one calf were without effect. No difference was observed in the amount of grain consumed per pound of gain or in the incidence of scours between the two groups.

Since the calves showed no response to the vitamin B_{12} supplementation, it appears that the young calf does not require any additional vitamin B_{12} in the calf starter when weaned from milk at an early age. It is possible that the calf obtains sufficient vitamin B_{12} from milk and milk products for its needs and stores this vitamin until rumen synthesis begins. It is also probable that vitamin B_{12} synthesis occurs at approximately 1 mo. of age since the experimental animals were weaned from milk at that time.

Summary

The supplementation of a vitamin B_{12} concentrate (A.P.F. No. 3) to an all plant-protein calf starter was without effect on the growth of calves to 90 days of age when weaned from milk at 28 days of age. Weekly intra-muscular injections of crystalline vitamin B_{12} (total of 1 mg.) to one calf after weaning from milk also was of no value. There was no difference in feed efficiency or incidence of scours whether or not A.P.F. was fed.

Literature Cited

Abelson, P. H. and H. H. Darby. 1949. The synthesis of vitamin B_{12} in the digestive system of the sheep. Science 110:566.

Catron, D. and C. D. Culbertson. 1949. Faster gains with A.P.F. Iowa Agri. Exp. Farm. Sci. 3:3.

Catron, D. and J. J. Wallace. 1949. Farm tests with A.P.F. Iowa Farm Sci. 4:19.

Collins, R. A., L. S. Dietrich and C. A. Elvehjem. 1950. Significance of vitamin B_{12} in milk diets. Fed. Proc. 9:355.

Hartman, A. M., L. P. Dryden and C. A. Cary. 1949. Vitamin B_{12} in milk, the role of B_{12} in the normal mammal, relation of B_{12} to the utilization of other milk constituents, and the role of milk and milk products as sources of B_{12} in the diet of normal mammals. Release, Bur. Dairy Ind. U.S.D.A., April.

Hogan, A. G. and G. G. Anderson. 1949. Vitamin B_{12} in swine nutrition. Fed. Proc. 8:355.

Johnson, B. C. 1950. The role of vitamin B_{12} in ruminant and non-ruminant nutrition. Presented before the Amer. Chem. Soc. meeting, Philadelphia, April.

Johnson, E. L. 1949. A.P.F. for poultry. Iowa Farm Sci. 3:3.

Lillie, R. J., C. A. Denton and H. R. Bird. 1948. Relation of vitamin B_{12} to the growth factor present in cow manure. Jour. Biol. Chem. 176:1477.

Richardson, L. R., L. G. Blaylock, H. L. German and R. M. Sherwood. 1949. Amino acids and vitamin B_{12} as supplements to plant proteins for growing chicks. Fed. Proc. 8:393.

Rubin, M. and H. R. Bird. 1946. Chick growth factor in cow manure. 1. Its non-identity with chick growth factors previously described. Jour. Biol. Chem. 163:387.

Whitson, D., H. W. Titus and H. R. Bird. 1946. The effect of feeding cow manure on egg production and hatchability. Poultry Sci. 25:143.

DISTRIBUTION OF P^{32} IN THE TISSUES OF A STEER FED GRASS FROM LAND THAT RECEIVED LABELED FERTILIZER[1]

RAY L. SHIRLEY,[2] GEORGE K. DAVIS,[2] AND J. R. NELLER[3]
Florida Agricultural Experiment Station

THE possibility of following an element from fertilizer through the soil and the forage to the animal has often been suggested as an application of isotopic elements, but to the writers' knowledge, no one has actually reported such an experiment, although the practice of using plants to synthesize compounds for experiments with animals is well known. In the fall of 1949, an area of Marlboro fine sandy loam was fertilized with a superphosphate fertilizer containing radioactive P^{32} and sown with fescue grass. Due to dry weather the fescue grass failed and the area was replanted with oats. A mixture of fescue and oats was harvested which weighed 1260 grams and contained sufficient P^{32} to give off approximately 75,000 beta degradations per minute as measured with a dipping-type Geiger-Mueller tube.

A young steer weighing 420 pounds was put in a digestion rack and fed the grass at 6 p.m. The steer finished the dried grass by noon of the following day and was then allowed to eat a cured mixed hay *ad libitum* until he was sacrificed the next morning at 9 a.m. Three fecal and urinary collections were made at approximately 12-hour intervals after the labeled grass was fed. After the sacrifice, the contents of the various segments of the alimentary tract, as well as the principal organs and tissues were separated and assayed for radioactivity. All samples were wet-digested with concentrated nitric acid, and made up to volume in volumetric flasks, and aliquots taken for isotope analysis using immersion-type Geiger-Mueller tubes in conjunction with commercial scalers.

Approximately 45 percent of the isotope in the grass was present in the contents of the various segments of the alimentary tract with most of it (36.3 percent) in the rumen and reticulum contents. The collected feces and urine contained a total of 1.34 and 1.54 percent, respectively.

[1] Published with the permission of the Director of the Florida Agricultural Experiment Station. The labeled fertilizer was received from the Bureau of Plant Industry, U. S. D. A., Beltsville, Maryland after allocation from the Atomic Energy Commission Isotopes Division, Oak Ridge, Tennessee.

[2] Department of Animal Husbandry and Nutrition.
[3] Department of Soils.

No isotope was found in the feces during the first 12 hours, but 0.92 percent of the dose was present in 24 hours. In the case of the urine 0.77 percent was found present by the end of the first 12 hours after the steer received the grass.

The following tissues were found to have the indicated values for percent dose of the isotope per 100 grams of sample: femur, 0.06; rib, 0.09; vertebra, 0.24; whole blood, 0.05; and washed blood cells, 0.03. Values for the percent dose in other organs and tissues were: adrenals, 0.03; bile, 0.12; bladder, 0.02; brain, 0.01; gall bladder, 0.01, heart, 0.25; kidney, 0.41; liver, 1.95; lungs, 1.18; pancreas, 0.16; parotid glands, 0.11; spleen, 0.30; salivary glands, thyroid, hair and hide, 0.00.

The wide distribution of the isotope in the tissues of the steer indicates that the plant not only utilizes the applied fertilizer but contains it in such form that it may be readily assimilated by a young growing animal.

SIGNIFICANCE OF THE DIFFERENCES IN DIGESTIBILITY OF FEEDS BY CATTLE AND SHEEP[1, 2]

MARY ANN CIPOLLONI,[3] BURCH H. SCHNEIDER,[3] HENRY L. LUCAS,[4] AND HELEN M. PAVLECH[5]

West Virginia Agricultural Experiment Station and University of North Carolina

THE efficiency with which cattle and sheep digest various feeds has been considered to be essentially the same by many investigators. As a result, data for the two species are usually combined in tabulating average digestion coefficients, and these then are applied to both species. In the most recent compilation of digestibility data (Schneider, 1947), however, the values determined for sheep and for cattle have been tabulated separately.

In the later compilation, which is the most complete to date, 71.5 percent of the digestion trials with ruminants were conducted with sheep, 27.5 percent with cattle, and 1 percent with goats. Yet, in 1945, the cattle population in the United States was 82,654,000 and the sheep population 41,224,000 (U. S. Department of Commerce, 1948). Jennings (1946) estimated that the total feed consumption by cattle and sheep in the United States was 183,411,000 tons for the year beginning October 1, 1941. Ninety-four percent of this amount was consumed by cattle and only 6 percent by sheep. Although the feed consumption by ruminants in the United States is predominately by cattle, the majority of the digestion studies have been with sheep. It thus seems of greatest importance that the question of whether or not the digestion coefficients for the two species are interchangeable be investigated critically.

This question has been studied before. Direct comparisons of the digestive efficiency of cattle and of sheep fed identical rations have been made by the following investigators: Frear (1890), Hutchinson (1895), Bartlett (1904), Kellner (1906), Tangl and Weiser (1906), Voeltz *et al.* (1913), Armsby (1917), Neidig *et al.* (1921), Hamilton

[1] Supported in part by a grant from Swift & Company, Chicago, Illinois. Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 423.

[2] From a thesis submitted by Mary Ann Cipolloni in partial fulfillment of the requirements for the degree of Master of Science at West Virginia University.

[3] West Virginia University. Present address: The State College of Washington.

[4] Institute of Statistics, University of North Carolina (Raleigh Campus).

[5] West Virginia University.

TABLE 1. NUMBERS OF TRIALS AND AUTHORS PER FEED SELECTED FOR STUDY

Feed Names	Number of digestion trials with			Number of authors investigating		
	Cattle	Sheep	Total	Cattle	Sheep	Total
	Dry Roughages (including hays) fed alone					
Alfalfa hay	88	144	232	17	21	38
Alfalfa hay, dehydrated	10	18	28	2	5	7
Clover hay	31	105	136	5	39	44
Clover hay, red	25	28	53	6	7	13
Clover grass mixed	46	63	109	5	14	19
Oat hay	22	26	48	2	4	6
Soybean hay	20	16	36	5	2	7
Timothy hay	57	63	120	9	13	22
Timothy grass weeds mixed hay	14	21	35	4	5	9
Corn fodder	25	20	45	7	5	12
Corn stover	14	15	29	3	6	9
Rice straw	13	10	23	3	6	9
Oat straw	7	28	35	3	2	5
13 feeds	372	557	929	71	129	200
	Concentrates with digestibility determined "by difference"					
Barley grain	22	39	61	3	8	11
Corn grain	40	28	68	8	8	16
Cottonseed feed	9	22	31	3	4	7
Linseed oil meal	59	22	81	5	6	11
Oat grain	21	66	87	2	13	15
Potato flakes or flour	16	30	46	2	5	7
Soybean Oil meal	25	21	46	5	3	8
Wheat bran	63	49	112	9	13	22
8 Feeds	255	277	532	37	60	97
	Silages fed alone					
Alfalfa	63	13	76	3	4	7
Clover	11	20	31	4	8	12
Clover grass	11	32	43	4	5	9
Corn	121	60	181	22	17	39
Grass	12	80	92	2	11	13
Sunflowers	14	14	28	4	5	9
6 Feeds	232	219	451	40	49	89
Grand Total	859	1053	1912	148	238	386

(1927), Forbes *et al.* (1937), Lathrop and Bohstedt (1937), Wolberg *et al.* (1940), Briggs *et al.* (1947), Watson *et al.* (1948) and Jordan and Staples (1951). After this review of the literature, however, it does not seem possible to state outright that sheep have poorer or better digestive powers than cattle or that the two species are identical in this respect. Rather, it seems possible only to say that differences between these two species exist, and that the direction and magnitude of these differences may be functions of the feed and of the nutrient involved. With this possibility in mind, a statistical study of the published digestibility data, which allows comparisons of sheep and cattle, has been made.

Method

The data were taken from the compilation, *Feeds of the World, Their Digestibility and Composition* (Schneider, 1947). Feeds selected for this study were those having two or more authors reporting digestion trials and those having nine or more digestion trials reported per animal species. A total of 27 feeds with 1912 digestion trials and 386 authors was included.

For convenience in handling the data, three main classifications of feeds were used: dry roughages, silages, and concentrates. Table 1 lists the feeds studied and the number of investigators reporting the data. The data include the proximate chemical analyses and the digestion coefficients for crude protein, crude fiber, nitrogen-free extract, and ether extract. Also included are digestion coefficients for organic matter and values for total digestible nutrients. Means for the digestion coefficients and percentages of proximate nutrients were tabulated for each author on each feed on each species of animal. Analyses of variance and covariance were then conducted on the author means for each of the three feed classes separately, using the method of weighted squares of means (Snedecor, 1946).

The proximate nutrients were considered as the independent variables in the covariance analysis. Adjustment for composition was necessary because the feeds were not all studied at the same laboratory and did not have the same proximate composition. Schneider and Lucas (1950) have shown that a substantial portion of the variation in digestion coefficients is associated with proximate composition. Obviously, then, a comparison of cattle with sheep would not be fair unless adjustment for composition were made.

Results

The mean squares after covariance adjustment for composition (table 2) reveal that, in the case of dry roughages, significant differences between species of animals exist for the digestibility of organic matter, crude fiber, and nitrogen-free extract, and for the content of total digestible nutrients. The table also shows that there is a species-by-feed interaction for the digestibility of crude protein in the case of

TABLE 2. MEAN SQUARES FOR DIGESTION COEFFICIENTS AND TOTAL DIGESTIBLE NUTRIENTS AFTER COVARIANCE ADJUSTMENT FOR PROXIMATE COMPOSITION

Variance Source	Degrees of Freedom	Organic Matter Mean Square	Crude Protein Mean Square	Crude Fiber Mean Square	N-F.E. Mean Square	Ether Extract Mean Squares	T.D.N. Mean Square
			Dry Roughages				
Between feeds	12	72	276	486	89	733	55
Between animal species	1	277**	9	300*	336**	259	312**
Species by feeds	12	10	221**	54	22	87	9
Error	170	22	49	53	25	236	15
			Silages				
Between feeds	5	271	67	1,382	45	280	205
Between animal species	1	103	9	26	93	938**	100
Species by feeds	5	62	19	120	52	135	54
Error	73	34	148	72	43	81	32
			Concentrates				
Between feeds	7	65	668	4,920	128	419	76
Between animal species	1	72	66	1,895	39	5,202**	71
Species by feeds	7	48	24	4,768	62	4,552**	50
Error	77	33	62	2,794	49	522	34

* Statistically significant at the 5 percent level.
** Statistically significant at the 1 percent level.

dry roughages. This means that on some feeds cattle digest protein significantly better than do sheep, but on other feeds the reverse is true. In the case of silages, a significant difference between the two ruminant species was found only with ether extract. Although significant differences did not exist for the other nutrients, the species mean squares for organic matter, nitrogen-free extract and total digestible nutrients are large enough compared to their errors to indicate a trend. For concentrates the picture is essentially the same as for silages; i.e., ether extract is digested significantly differently by the two species. However, there is also a significant species-by-feed interaction for ether extract. This shows that the difference varies considerably from feed to feed. Although the between-species mean square for total digestible nutrients in con-

centrates is not significant, it is again large enough to suggest a trend.

In order to note how sheep and cattle differ on the average for the three feed classes, the species differences in digestion coefficients adjusted to the same proximate composition are shown in table 3. It is seen that the average differences for dry roughages are in favor of cattle on all nutrients. The average differences for silage, although significant only with ether extract, indicate that cattle tend to digest silages better than do sheep. With concentrates, however, sheep tend to digest all nutrients better than do cattle.

Discussion

This study shows that for many nutrients in many feeds sheep and cattle differ with regard to their digestive powers. In some instances

TABLE 3. THE AVERAGE DIFFERENCES IN DIGESTIBILITY BY CATTLE AND SHEEP OF THREE CLASSES OF FEEDS AFTER ADJUSTMENT FOR PROXIMATE COMPOSITION[1]

Feed Classes	Organic Matter	Crude Protein	Crude Fiber	Nitrogen-free Extract	Ether Extract	Total Digestible Nutrients
Dry roughages	3**	1	4*	4**	4	3**
Silages	3	1	2	3	8**	3
Concentrates	—2	—2	—4	—2	—20**	—3

[1] Positive values indicate that cattle digest better than sheep. Negative values indicate that sheep digest better than cattle.
* Significant at the 5 percent level.
** Significant at the 1 percent level.

cattle are the more efficient, in other instances sheep. In general, then, more accurate assessment of nutritive value will be attained if, when working with cattle, one uses digestion coefficients obtained with cattle, and if when working with sheep, those obtained with sheep are used. The fact that sometimes one of these two species is superior and sometimes the other, certainly is no reason for concluding that digestion coefficients can be used interchangeably. This interaction in itself is argument for employing separate values for cattle and for sheep.

The species differences and interaction observed in the case of protein digestibility for roughages is in agreement with the recent findings of Forbes (1950). He reported the protein of low-protein forages to be better digested by sheep than by cattle, and that this difference disappears with high-protein forages.

Since in the United States about 16 times as much feed is fed to cattle as is fed to sheep, it is important that more digestibility work

be done with cattle, or that appropriate corrections to be applied to sheep data be derived.

Summary and Conclusions

Published data which allow the comparison of the digestive powers of cattle and sheep were analyzed statistically. Comparisons were made for the digestibility of organic matter, crude protein, crude fiber, N-free extract, and ether extract, and the contents of total digestible nutrients in each of the three feed classes, dry roughages, silages, and concentrates. To make the comparisons fair, covariance adjustment for proximate composition was conducted. Specific differences in the digestibility of the organic matter, crude fiber, nitrogen-free extract, and ether extract, and in the total digestible nutrient content of dry roughages were found to be statistically significant. In the case of silages and concentrates, species differences were significant only for ether extract. The interaction, species-by-feeds, was significant for the digestibility of protein in dry roughages and the digestibility of ether extract in concentrates, indicating that the differences in the digestibility favor cattle with certain feeds and sheep with others. Other differences, although not significant, were large enough to suggest a trend.

From the results, it was clear that greater accuracy will be attained if digestibility data to be used for cattle are obtained with cattle, and similarly for sheep.

Literature Cited

Armsby, H. P. 1917. The nutrition of farm animals. 603. New York.

Bartlett, J. M. 1904. Digestion experiments with sheep and steers. Maine Agr. Expt. Sta. Bul. 110:185.

Briggs, H. M., W. D. Gallup, V. G. Heller, A. E. Darlow, and F. B. Cross. 1947. The digestibility of dried sweet potatoes by steers and lambs. Okla. Agr. Expt. Sta. Tech. Bul. T-28, 5.

Forbes, R. M. 1950. Protein as an indicator of pasture forage digestibility. Journal of Animal Science 9:231.

Forbes, E. B., J. W. Bratzler, A. Black, and W. W. Braman. 1937. The digestibility of rations by cattle and sheep. Pa. Agr. Expt. Sta. Bul. 339:3.

Frear, W. 1890. Digestibility of the corn crop and of the silage and fodder made from it. Digestion experiment. Pa. Agr. Expt. Sta. Ann. Rpt., 45.

Hamilton, T. S., C. H. Kick, and H. H. Mitchell. 1928. Steers digest two hays better than do sheep. Ill. Agr. Expt. Sta. 41st Ann. Rpt., 117.

Hutchinson, W. L. 1895. Chemical work digestion experiments. Miss. Agr. Sta. 8th Ann. Rpt., 78.

Jennings, R. D. 1946. Feed consumed by livestock, 1941–42, by states. U.S.D.A., Bureau of Agricultural Economics, 40.

Jordan, R. M. and G. E. Staples. 1951. Digestibility comparisons between steers and lambs fed prairie hays of different quality. Journal of Animal Science 10:236.

Kellner, O., A. Koehler, W. Zielstorff, and F. Barnstein. 1906. Vergleichende Versuche ueber die Verdauung von Wiesenheu und Haferstroh durch Rind und Schaf. Landw. Vers. Sta. 63:313.

Lathrop, A. W., and G. Bohstedt. 1938. Oat mill feed. Its usefulness and value in livestock rations. Wisc. Agr. Expt. Sta. Res. Bul. 135.

Neidig, R. E., R. D. Snyder, and C. W. Hickman. 1921. Sunflower silage digestion experiments with cattle and sheep. Jour. Agr. Res. 20:881.

Schneider, Burch H. 1947. Feeds of the world, their digestibility and composition. Morgantown, W. Va., W. Va. Agr. Expt. Sta.

Schneider, Burch H. and Henry L. Lucas. 1950. The magnitude of certain gross sources of variability. Journal of Animal Science. 9:504.

Snedecor, G. 1946. Statistical Methods. 4th Edition. The Iowa State College Press, Ames, Iowa. 291.

Tangl, F. und S. Weiser. 1906. Zur Kenntnis des Naehrwertes einiger Heuarten. Landw. Jahrb. 35:159.

U. S. Dept. of Commerce. 1948. Bureau of Census. Statistical abstract of the United States. Washington, D. C., 692.

Voeltz, W., J. Paechtner, und A. Baudrexel *et al.* 1913. Fuetterungsversuche mit fluessiger waermer Kartoffelschlempe und mit getrockneter Kartoffelschlempe im Vergleich zum Palmkernkuchen. Landw. Jahrb. 45:325.

Watson, C. J., W. M. Davidson, J. W. Kennedy, C. H. Robinson, and G. W. Muir. 1948. Digestibility studies with ruminants. XII. The comparative digestive powers of sheep and steers. Sci. Agr. 28:357.

Wolberg, F. B., R. E. Hodgson, J. C. Knott, and U. S. Ashworth. 1940. The digestibility of corn silage and mixed hay as determined by dairy cattle and sheep. Western Div. Amer. Dairy Sci. Assoc. Proc. 26th Ann. Meeting, 72.

THE USE OF DIGESTIBLE ENERGY IN THE EVALUATION OF FEEDS

G. P. LOFGREEN[1]
University of California

THE Morrison feeding standards, which are undoubtedly the most widely used standards in the United States, are based upon total digestible nutrients (TDN) as a measure of the energy requirements of animals and the energy value of feeds. The term TDN is only an approximate measure of the food energy available to the animal after the digestion losses have been deducted. Morrison (1948) and others (Forbes, *et al.*, 1943; Kleiber, *et al.*, 1945; Maynard, 1947 and Mitchell, 1942) have discussed the advantages and disadvantages of this system in comparison to other expressions of the energy value of feeds. It is not the purpose of this paper to discuss these various methods nor to attempt to suggest which should be used. Since the TDN system has been so widely accepted and because of the difficulty of a rapid and complete change to another system it seems desirable to attempt to improve the method now used and to obtain more information as to its application. Experiments are often conducted in which it is necessary or desirable to determine the TDN content of feeds or rations. Any procedure which would facilitate such a determination or increase its accuracy would prove valuable.

One of the main criticisms of the determination of TDN is the number of chemical analyses required and the inaccuracy of some of the methods. There are a number of objections to the usual scheme of routine feed analysis commonly employed in the determination of TDN, especially in the methods of determining the carbohydrate portion. It seems, therefore, that it would be a major improvement if some method could be devised to determine TDN which would not involve the determination of these various constituents.

Maynard (1947) states that some of the uncertainties of the measurement of TDN could be overcome by measuring digestible energy. The mere measurement of digestible energy, however, without the establishment of its relationship to the TDN content of the feeds would be of little value since the standards according to which animals are fed most

[1] The author wishes to thank H. R. Guilbert and H. Goss for allowing him to use the samples for the digestion trials conducted by them.

widely are in terms of TDN. For example, in digestion trials reported by Forbes, *et al.* (1940) the TDN content of alfalfa-molasses silage averaged 20.1 percent while the digestible energy was 59.9 percent. The TDN expressed on the dry basis amounted to 67.6 percent. The relationship between 20.1 or 67.6 percent TDN and 59.9 percent digestible energy must be clarified before the digestible energy determination would be of much value in evaluating the silage according to our present methods.

The calculation of the percent TDN from the data obtained in digestion trials can be represented as follows:

$$(1)\quad \text{TDN} = 100 \times \frac{(\text{DCP}) + (\text{DCF}) + (\text{DNFE}) + (\text{DEE} \times 2.25)}{(\text{CP}) + (\text{CF}) + (\text{NFE}) + (\text{EE}) + (\text{ash}) + (\text{moisture})}$$

where CP, CF, NFE and EE represent the total amounts and DCP, DCF, DNFE and DEE the digestible amounts of crude protein, crude fiber, nitrogen free extract and ether extract in the feed.

Similarly the percent of digestible energy (DE) can be represented as:

$$(2)\quad \text{DE} = 100 \times \frac{\frac{\text{energy}}{\text{in DCP}} + \frac{\text{energy}}{\text{in DCF}} + \frac{\text{energy}}{\text{in DNFE}} + \frac{\text{energy}}{\text{in DEE}}}{\frac{\text{energy}}{\text{in CP}} + \frac{\text{energy}}{\text{in CF}} + \frac{\text{energy}}{\text{in NFE}} + \frac{\text{energy}}{\text{in EE}} + \frac{\text{energy}}{\text{in ash}} + \frac{\text{energy/n}}{\text{moisture}}}$$

From the data presented in table 1 it is possible to calculate the TDN content of a sample of alfalfa hay by the use of formula (1):

$$\text{TDN} = 100 \times \frac{8.6 + 12.7 + 30.8 + (0.6 \times 2.25)}{13.0 + 26.0 + 41.2 + 1.8 + 9.9 + 8.1} = 53.5$$

By use of average heats of combustion values for proteins, carbohydrates and fats it is possible to calculate the theoretical digestibility of energy according to formula (2):

$$\text{DE} = 100 \times \frac{48.6 + 54.0 + 127.8 + 5.6}{73.4 + 110.5 + 171.0 + 16.9 + 0 + 0} = 63.5$$

In the latter calculation the 9.9 grams of ash and 8.1 grams of water have no energy value with the result that the 63.5 percent digestible energy is not affected by the amount of water and ash in the feed while the 53.5 percent TDN would be. Digestible energy, therefore, is affected only by the organic matter content of the feed. In order to place the 63.5 percent digestible energy on the same basis as the 53.5 percent TDN, i.e., relate it to the total feed, the 63.5 percent digestible energy must be multiplied by the percentage of organic matter of the feed. In the above example the alfalfa hay contained 82 percent organic matter. The adjustment would therefore be $\frac{63.5 \times 82}{100} = 52.1$. When related to the total feed the digestible energy is thus not far different

from the TDN, the two values being 52.1 and 53.5 percent respectively.

A careful consideration of the relationship reveals another adjustment which must be made in order to express digestible energy on the same basis as TDN. In the determination of digestible energy heats of combustion are determined on the feeds and feces and the energy digested is obtained by difference. Since the bomb calorimeter automatically

TABLE 1. THE DIGESTIBLE NUTRIENTS AND THEORETICAL DIGESTIBLE ENERGY OBTAINED IN A DIGESTION TRIAL ON ALFALFA HAY

Item	Crude protein	Crude fiber	Nitrogen free extract	Ether extract	Ash	Moisture
Nutrient content per 100 grams of feed, grams	13.0	26.0	41.2	1.8	9.9	8.1
Heat of Combustion, Kilocalories per gram[1]	5.65	4.25	4.15	9.40	0	0
Energy consumed per 100 grams of feed, Kilocalories	73.4	110.5	171.0	16.9	0	0
Nutrients digested per 100 grams of feed, grams	8.6	12.7	30.8	0.6	–	–
Energy digested per 100 grams of feed, Kilocalories	48.6	54.0	127.8	5.6	–	–

[1] The figures 5.65 for protein, 4.15 for nitrogen free extract, and 9.40 for ether extract are average heats of combustion values reported by Atwater (1899) for proteins, carbohydrates and fats in a mixture of foods. The value of 4.25 is the heat of combustion of cellulose.

gives the various constituents their proper energy value, the fat in the total feed consumed as well as that in the digested portion is given a value of approximately 2.25 times that of the carbohydrate portion. This is not true in the case of the calculation of TDN where only the digested fat is given the extra value while the fat in the feed consumed is given the same value as carbohydrates and proteins. This would result in a discrepancy between digestible energy and TDN which would increase as the fat content of the ration increased. In the example in table 1 the alfalfa hay contained 1.8 percent ether extract. This would amount to 2.2 percent of the organic matter. In the determination of digestible energy the bomb calorimeter would give the 2.2 percent ether extract a value of approximately 2.25×2.2 or 4.9. This results in

a value of 4.9—2.2 or 2.7 more than it would have received had it been given the same value as carbohydrate. If this same thing had been done in the calculation of TDN it would have resulted in the sum of the digestible nutrients, with the fat multiplied by 2.25, being divided by a value greater than 100 (see formula 1). Therefore, in order to express digestible energy on the same basis as TDN the digestible energy value previously adjusted to the basis of the total feed must be multiplied by the ratio $\frac{102.7}{100}$ thus: $52.1 \times \frac{102.7}{100} = 53.5$. The digestible energy and the TDN when expressed on the same basis are now equal. Theoretically, therefore, it appears that it is possible to calculate a value equivalent to TDN by use of the bomb calorimeter rather than the determination of the complete proximate composition of the feeds and feces. Such a determination could be made according to the following procedure:

1. Determine moisture, ash, ether extract and energy on the feed.
2. Determine moisture and energy on the feces.
3. Calculate the percent of the gross energy which is digested.
4. Calculate the conversion factor by the formula:

$$(3)\ F = \frac{OM}{100} \times \frac{100 + (EE \times 2.25) - EE}{100}$$

where OM represents the percent organic matter in the feed and EE represents the percent ether extract in the organic matter.

5. Multiply the percent digestible energy by the conversion factor, F.

In the conventional method of determining TDN from a digestion trial using one feed and four animals it would be necessary to determine a complete proximate analysis on at least five samples in duplicate. This would amount to ten determinations of moisture, ash, nitrogen, ether extract and crude fiber. From the same trials the TDN value of the feed could be calculated by the calorimetric method from ten determinations of moisture and energy and two of ether extract and ash since these latter two constituents need be determined only on the feed.

The TDN value calculated by the calorimetric method would be more accurate as a measure of the energy value of the feed than the TDN content determined by the conventional method because the bomb calorimeter would give the various nutrients their proper heat of combustion values. In the conventional method one has to assume that all the proteins and carbohydrates in all feeds are of equal value and that all fats have an energy value of 2.25 times that of carbohydrates and proteins. Such assumptions may result in improper evaluation of a feed or ration.

Because of the possibility of great savings in time and in the number of chemical analyses and the promise of increased accuracy the suggested procedure has been investigated and compared with the conventional method for the determination of TDN.

TABLE 2. COMPARISON OF TOTAL DIGESTIBLE NUTRIENTS OBTAINED BY THE CONVENTIONAL METHOD WITH VALUES CALCULATED FROM DIGESTIBLE ENERGY

Ration	TDN Value of Ration (as fed)	
	Conventional Method	Calorimetric Method
	percent	percent
	56.6	57.9
	55.6	57.0
Alfalfa Hay	55.2	57.3
	53.5	56.0
	16.4	16.2
Alfalfa Hay	16.0	15.6
Wet Beet Pulp	16.2	15.9
	16.4	16.1
	14.8	14.2
Alfalfa Hay	15.1	14.5
Wet Beet Pulp	15.2	14.4
Molasses	15.0	14.4
	34.5	40.8
	39.9	40.5
Flax Hulls	35.7	33.0
	33.9	40.5
	56.7	53.8
Various proportions of	57.3	55.0
Oat Hay, Barley, Oats,	56.3	54.3
Dried Beet Pulp, Cotton-	55.3	53.3
seed meal, Limestone	55.2	52.1
and salt	57.1	54.2
	51.6	48.4

Experimental

The TDN content of the feeds used in 23 digestion trials was determined by the conventional method. By applying the conversion factor calculated by use of formula (3) digestible energy has been related to the TDN content. Guilbert, Miller and Goss (1947) using sheep as the experimental animals conducted four digestion trials on alfalfa hay alone, four on alfalfa hay and wet beet pulp and four on alfalfa hay, wet beet pulp and molasses. Feed and feces samples from these trials have

been used in the present study. Four trials on flax hulls have been conducted with sheep by Guilbert and Goss (1944) and samples from these trials were also used in the comparisons presented herein. Seven additional trials have been conducted using beef bulls on rations consisting of oat hay and various proportions of oats, barley, dried beet pulp, cottonseed meal, limestone and salt. Chemical analyses were made according to the methods of the Association of Official Agricultural Chemists (1945). Gross energy determinations were made by use of a bomb calorimeter.

Results and Discussion

The TDN content of the feeds used in the 23 trials as determined by the conventional method and the TDN values calculated by the calorimetric method are presented in table 2.

Using the paired data system of analysis no significant difference was found between the two methods. Most of the differences which do occur are as small as or smaller than the differences between animals on the same ration.

These data indicate that a great saving in time and chemical analyses can be made by calculating the TDN value of feeds from the digestible energy. Where consistent small differences do appear in the values determined by the two methods those determined from digestible energy should be more representative of the true energy value of the feed since no assumptions need be made as to the relative value of the various nutrients as is done in the conventional method. The relatively good agreement between the two sets of values is reassuring, however, that the assumptions made in the determination of TDN by the conventional method may not lead to serious errors in most cases.

When the TDN value is determined from digestible energy by the proposed method it is unnecessary to determine separate coefficients of digestibility for the proximate principles. Even though this is a distinct advantage in the determination of TDN it does not allow one to evaluate similar feeds by applying average digestion coefficients to the determined proximate composition. Schneider, *et al.* (1950) have shown that the application of average digestion coefficients to the determined proximate principles results in a better estimate of the nutritive value of a feed than the direct use of an average value for TDN content. Even though the proposed method for the determination of the TDN value of feeds may have the disadvantage of not supplying coefficients of digestibility of all the proximate principles it should prove especially useful in experimental work where the TDN values of feeds and rations

actually must be determined rather than estimated from tables of average digestion coefficients. Of course, one would usually desire to determine the digestible protein content in either case.

Brody (1935) has suggested that the TDN content of a feed be estimated from digestible energy by assuming that one pound of TDN is equal to 1814 kilocalories. Such a factor has the disadvantage of being only an average value and could lead to erroneous results when applied to different individual feeds or mixtures of feeds. For example, in the five feeds or feed combinations listed in table 2 the amount of digestible energy equal to one pound of TDN varies from 2057 to 2457 kilocalories. The use of the factor 1814 in the case of these feeds would result in a large error as would any average factor. One of the advantages of the method proposed in this paper for calculating the TDN value of feeds from digestible energy is that the conversion factor calculated according to equation 3 is specific for each feed or combination of feeds.

One of the objections to a change from the TDN system of evaluating feeds has been that the great body of data which has been compiled on digestion coefficients of the proximate constituents would no longer be of much value. Because of the close relationship of TDN to digestible energy it would, however, be possible to calculate from these data the approximate percentage of gross energy which would be digested by merely dividing the percent TDN by the proposed factor (F in equation 3). To evaluate a sample of feed, therefore, one need merely to determine its heat of combustion and apply the energy digestion coefficient calculated from the average TDN of a similar feed in the tables of composition to arrive at an estimate of the amount of energy which would be digested. For example, the factor for alfalfa hay, all analyses, given in Morrison's (1948) tables of feed composition would be 0.848. By applying this factor to 50.3 percent TDN an approximate digestion coefficient of 59.3 percent for energy would be obtained. This coefficient could then be applied to the heat of combustion of an alfalfa hay sample to estimate its content of digestible energy. Such a procedure would make it possible to use this body of digestibility data if the digestible energy system were used to evaluate feeds rather than the system based upon TDN.

Summary

A method is presented by which it is possible to calculate a value closely approximating the total digestible nutrient content of feeds and

rations from digestible energy. The method provides for a saving in time and in the number of chemical analyses which need be made.

It is pointed out that the use of the calorimetric method results in a more accurate estimate of the energy value of a feed or ration than the conventional method of determining total digestible nutrients.

Literature Cited

Association of Official Agricultural Chemists. 1945. Methods of analysis. 6th ed. Washington, D. C. 932 pp.

Atwater, W. O. 1899. Discussion of the terms digestibility, availability, and fuel value. 12th An. Rep. Storrs Agr. Exp. Sta. pp. 69–110.

Brody, S. 1935. Report of the conference on energy metabolism. National Research Council. Washington, D. C. 93 pp.

Forbes, E. B., J. W. Bratzler and C. E. French. 1940. The utilization of certain feeding stuffs by cattle. Penn. Agr. Exp. Sta. Bul. 391, 14 pp.

Forbes, E. B. and R. W. Swift. 1943. Conditions affecting the digestibility and the metabolizable energy of feeds for cattle. Penn. Agr. Exp. Sta. Bul. 454, 34 pp.

Guilbert, H. R. and H. Goss. 1944. Digestion experiments with range forages and flax hulls. Calif. Agr. Exp. Sta. Bull. 684, 10 pp.

Guilbert, H. R., R. F. Miller and H. Goss. 1947. Feeding value of sugar-beet by-products. Calif. Agr. Exp. Sta. Bul. 702, 24 pp.

Kleiber, Max, W. M. Regan and S. W. Mead. 1945. Measuring food values for dairy cows. Hilgardia 16:511.

Maynard, L. A. 1947. Animal Nutrition. New York. 2nd. ed. 494 pp.

Mitchell, H. H. 1942. The evaluation of feeds on the basis of digestible and metabolizable nutrients. JOURNAL OF ANIMAL SCIENCE 1:159.

Morrison, F. B. 1948. Feeds and feeding. Ithaca, New York. 21st ed. 1207 pp.

Schneider, B. H., H. L. Lucas, H. M. Pavlech and M. A. Cipolloni. 1950. The value of average digestibility data. JOURNAL OF ANIMAL SCIENCE 9:373.

RELATIONS BETWEEN SOME BODY MEASUREMENTS AND CERTAIN PERFORMANCE CHARACTERS IN MILKING SHORTHORN STEERS

M. L. Kohli,[1] A. C. Cook,[2] and W. M. Dawson [2]
U. S. Department of Agriculture

As a part of the record of performance studies with Milking Shorthorn steers at the U.S.D.A. Research Center, Beltsville, Maryland, various body measurements of the steers were taken on foot before slaughter. These body measurements were taken to determine whether there exists any association between the measures themselves and between them and certain performance characters. These relationships may be of practical value to a breeder in the selection of his stock.

This paper is based on five measurements—height at withers, height to floor of chest, heart girth, width at shoulders, length of body; and their relationship to average daily gain, efficiency of feed utilization, and the age of the steers when they reach 900-pounds live weight. Associations of birth weight, age and weight at weaning with these measurements and rate and efficiency of gain and final age of the steers have also been included in this study.

Review of Literature

Black *et al.* (1938) concluded from the analysis of data of 50 steers of beef, dual-purpose, and dairy breeding that at 900-pounds live weight the taller and rangier type of animal has a slight tendency to be less efficient in the use of feed. Width of shoulder and width of chest had small positive correlations with rate and efficiency of gain, and heart girth showed practically no correlation with these factors.

Hultz and Wheeler (1927) in a study of 2-year-old Hereford steers concluded that low-set type steers make slightly more rapid and economical gains during a 156-day feeding period than do intermediate or rangy type steers. They report that a 2-year-old steer has the appearance of low-setness when the proportions of his chest depth, heart girth, and paunch to his height at the withers are great.

[1] Guest research worker from The Civil Veterinary Department, Punjab, India.
[2] Animal Husbandmen, U. S. Department of Agriculture.

Acknowledgement.—The authors wish to acknowledge the help of Dr. R. G. Schott, Bureau of Animal Industry, in reading and criticizing the manuscript.

Knapp and Cook (1933) working with a small number of steers have shown that at 900-pounds body weight Milking Shorthorn steers fed in record of performance tests were not only taller but longer bodied than beef Shorthorn steers fed in a similar manner. Beef Shorthorns, however, were superior to Milking Shorthorns in heart girth, width of chest, and width of shoulder.

Lush (1928) studied changes in body measurements during fattening and (1932) the relation of body shape of feeder steers to rate of gain, dressing percentage, and value of dressed carcass. He found the correlations between body measurements of a large number of feeder steers and subsequent gains, dressing percentage, and values of the dressed beef to be low but statistically significant.

Schmidt and Patow (1938) studying the effect of environment on various body measurements of cattle found that with unfavorable conditions height measurements were hardly affected at all, width measurements were reduced, while length measurements, on the contrary, increased.

Severson and Gerlaugh (1917 a and b) made a statistical study of body weights, gains and measurements of steers during the fattening period and reported among others the following correlations: Between gain in live weight and increase in circumference of chest, 0.460; gain in live weight and increase in circumference of paunch, 0.306; and gain in live weight and increase in circumference of rear flank, 0.203.

Swett and Graves (1939) working with a large number of cows of varied breeding at a Chicago packing plant found that, in general, body measurements are highly correlated with live weight. The highest correlation they obtained was 0.82 for circumference of fore-chest with live weight.

So far as the authors are aware, no one has reported results on the association of body measurements among themselves and with performance characters for a fairly large population of dual-purpose steers or for these relationships when the final weight is practically constant.

Material and Methods

The 157 steers used in this study were all purebred Milking Shorthorns. They were raised and fed in the record of performance project from 1932 to 1949, inclusive, at the Agricultural Research Center, Beltsville, Maryland. The steers were progenies of 125 different dams and 29 different sires. A majority of the dams used in this experiment had only 1 steer offspring, 26 had 2, and 3 had 3 offspring. Each sire

produced from 1 to 13 steers, 17 sires having more than 5. Most of the animals were weaned at 500-pounds live weight, but of the first steers raised 9 were weaned at 245 days of age and 25 at 252 days of age. The change from age at weaning to weight at weaning was made in order to have the criteria at weaning comparable to those at slaughter.

The method of feeding also changed to some extent throughout this period of 18 years. Ninety-one of the first calves were hand-fed milk and the rest were nursed due to shortage of labor during war days. During the record of performance feeding period, from 500- to 900-pounds live weight, the concentrates fed were as follows: 35 calves got only corn (No. 2 shelled yellow corn) with total digestible nutrients (T.D.N.) of 80.1 percent; 26, corn and varying proportions of a mixture (wheat, linseed oil meal, bran, and corn); and 96, a mixture consisting of cracked shelled corn (5 parts), ground oats (3 parts), wheat bran (1 part), and linseed oil meal, 30.8 percent protein (1 part) by weight with a T.D.N. of 75.5 percent, and total digestible protein of 10.57 percent. No. 2 leafy alfalfa hay was given at the rate of approximately 1 pound to every 2 pounds of concentrate. Concentrate was full fed but in a quantity that the animals would clean up readily. All the animals used in this experiment were fed individually and did not have access to pasture.

The steers were slaughtered when they had reached a live weight of approximately 900 pounds. The mean was 903 ± 0.82 pounds. The average of 3 body weights taken on 3 days preceding slaughter was used as the final weight. Measurements were taken within 24 hours of the time of slaughter, practically all of them by the same operator to eliminate the variation from different operators handling the apparatus. For 52 animals the average of 2 repetitions of each measurement was obtained, while for the rest the average of 3 repetitions was available. This average of more than one repetition of the measurements was considered to be more reliable than only one repetition, according to the findings of Hetzer *et al.* (1950). The position on the animal where each measurement was taken is shown in figure 1. Efficiency was expressed as pounds of gain per 100 pounds of total digestible nutrients consumed during the fattening period.

To determine what the relationship would be when the weaning weight and methods of feeding were the same for all the steers in the sample, a group of 62 steers was selected from the 157 steers. The 62

steers were nursed as calves, weaned at approximately 500 pounds, and received the mixed concentrate described previously during the feeding period. Differences regarding the year and sire could not be controlled in this way. As the experiment progressed and sires were proved through

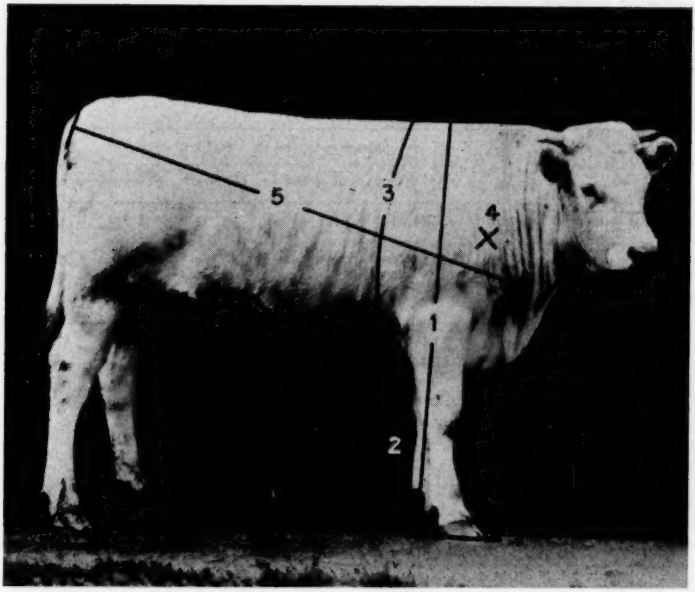


Figure 1. Milking Shorthorn steer showing location of measurements taken: 1. Height at withers; 2. Height to floor of chest; 3. Circumference of fore-flank or heart girth; 4. Width of shoulder; and 5. Length of body from pinbone to point of shoulder. The width of shoulder was taken through the body at the point marked x.

the performance of their progeny, sons of those with the best records were used in the breeding program.

Statistical analyses were made according to the methods of Fisher (1946), Snedecor (1948), and Wallace and Snedecor (1931).

Results and Discussions

For most of the characters studied between the group of 62 steers and the total group of 157, the means were not statistically different

(table 1). However, height at withers, days to weaning, and days to final weight were significantly less for the group of 62 steers than for the total sample. The differences in days to weaning and days to final weight may have been partly influenced by the fact that in the total group of 157 steers some of the animals were weaned at given ages and some at a given weight.

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR THE DIFFERENT CHARACTERS STUDIED

Characters studied		Means		Standard deviation		Differences between means
		157 steers	62 steers	157 steers	62 steers	
Height at withers	cm.	124.61	123.44	2.93	2.73	1.17**
Height at floor of chest	cm.	59.90	59.31	2.93	2.73	0.59
Circumference fore-flank	cm.	174.85	173.71	3.44	2.66	1.14
Width of shoulder	cm.	41.98	41.50	1.84	1.81	0.48
Length of body	cm.	138.67	137.06	4.73	4.24	1.61
Average daily gain	lbs.	1.65	1.74	0.24	0.33	0.09
Efficiency	lbs.	15.18	15.50	1.89	2.09	0.32
Days to weaning		231.41	206.00	30.04	25.55	25.41**
Days to final weight		472.71	438.90	50.29	43.19	33.81**
Birth weight	lbs.	79.89	77.71	10.17	9.54	2.18

* Significant at 0.05 level.
** Highly significant at 0.01 level.

Analyses of variance show that the different rations did not affect significantly the height at withers, height at floor of chest, and efficiency of gain, and that hand feeding milk and nursing did not affect significantly height at floor of chest, length of body, average daily gain, and efficiency (table 2). When the effects of years, as well as rations and type of nursing, were studied with these factors, so few groups were available for comparison that it was impossible to draw definite conclusions. However, there were indications that the group of 62 steers which nursed their dams, received the grain mixture in the latter part of

TABLE 2. MEAN SQUARES FOR BODY MEASUREMENTS AND ECONOMIC CHARACTERS OF 157 STEERS[1]

Source of variation	Degrees of freedom	Mean squares							
		Ht. at withers	Ht. at floor of chest	Length of body	Circumference fore-flank	Width of shoulders	Average daily gain	Final age	Efficiency
		cm.	cm.	cm.	cm.	cm.	lbs.	days	lbs.
Between rations within hand-fed and and nursed steers	4	6.65	10.02	81.65**	66.15**	18.62**	0.52**	5778.5*	8.50
Between hand-fed and nursed steers within ration	3	21.23*	19.87	36.30	66.63**	14.83**	0.13	17829.7**	4.3
Within	151	7.81	8.45	14.84	10.29	2.97	0.05	1768.0	3.52
Total	156								

[1] This table is a condensation of two analyses for each character studied. The variance between hand-fed and nursed steers and between rations has not been included in the table.

* Significant at 0.05 level.

** Highly significant at 0.01 level.

the experiment (table 3), and were produced by the later sires, were helped by these factors to reach weaning weight and final weight at earlier ages. They were more compact, made better average daily gains, and the efficiency of utilization of feed was also higher than the others. It would be desirable to have the rations and the method of raising the calves to weaning constant in a study of this kind.

Correlations between the five body measurements and rate and efficiency of gain, birth weight, and days to weaning and final weight were all quite low and in general were similar for the groups of 62 and 157 steers (table 4). Thirteen of the correlations between the body measurements and the other factors were significant for the group of 157 steers while only six were significant for the group of 62 steers. This indicates the need for the larger number of animals for such observations.

Height at withers, which is almost entirely a skeletal measurement, was significantly correlated with all the factors except efficiency of gain and circumference of fore-flank for 157 steers (table 4). With height at floor of chest it had the highest correlation, 0.75. This measurement, although it is not a part of height at withers, being taken at a slightly different position, also measures a portion of the height of the animal. With width of shoulder and average daily gain it had low but negative significant correlations. Thus there is a slight indication that the shorter the legs of a steer, the better would be its daily gain. With length of body, birth weight, and days to weaning and final weight, height at withers had low but significant positive correlations. No significant differences existed between the correlations for 62 steers and those for 157 steers for all these factors with height at withers. For the 62 steers none of the correlations were significant except those for height at floor of chest and width of shoulder. The result obtained by Black *et al.* (1938) showing a significant correlation between efficiency and height at withers does not hold true with this study. This may be due in part to the steers in their experiment being of several breeds, Shorthorn, Milking Shorthorn, Jersey, and Holstein.

Height at floor of chest, also a skeletal measurement, had significant positive correlations with birth weight and length of body; significant negative correlations with circumference of fore-flank and width of shoulder; and no significant correlations with the rest of the factors for 157 steers. There were no significant correlations between this measurement and the other measurements for the group of 62 steers, and there existed no significant differences between these correlations and those for the group of 157 steers. All the correlations were low. There is, however, a slight indication that in the Milking Shorthorns studied the

TABLE 3. MEANS OF THE DIFFERENT CHARACTERS STUDIED AS INFLUENCED BY HAND FEEDING, NURSING, AND THE DIFFERENT RATIONS FED

Environmental factors	No. of steers	Means								
		Height at withers	Height at floor of chest	Length of body	Circumference fore-flank	Width of shoulder	Days to weaning	Days to final weight	Efficiency	Average daily gain
		cm.	cm.	cm.	cm.	cm.			lbs.	lbs.
(Suckling period)										
Hand fed	91	125.42	60.34	139.89	175.32	42.14	247.82	494.96	15.00	1.61
Nursed	66*	123.50	59.29	136.98	174.20	41.76	208.79	442.04	15.45	1.71
(Feeding period)										
Corn	35	125.94	60.37	141.46	175.54	42.14	246.00	502.26	14.42	1.47
Corn and mixture	26	125.08	60.38	140.27	176.31	42.96	244.50	497.88	15.69	1.58
Mixture	96	124.00	59.59	137.22	174.20	41.66	222.55	455.12	15.33	1.74
Total	157	124.61	59.90	138.67	174.85	41.98	231.41	472.71	15.18	1.65

* Of these animals only 62 received the feed mixture.

TABLE 4. SIMPLE CORRELATION COEFFICIENTS BETWEEN DIFFERENT CHARACTERS FOR TWO GROUPS OF STEERS

Characters studied	No. of steers and differences	Height at floor of chest	Circumference fore-flank	Width of shoulder	Length of body	Average daily gain	Efficiency	Days to weaning	Days to final weight	Birth weight
Ht. at withers	157	+.75**	+.08	−.25**	+.38**	−.17*	−.13	+.21**	+.26**	+.23**
	62	+.75**	+.03	−.29*	+.22	+.04	−.10	+.15	+.06	+.16
	Difference	—	.05	.04	.16	.21	.03	.06	.20	.07
Ht. at floor of chest	157		−.20**	−.18*	+.23**	−.06	+.004	+.04	+.10	+.18*
	62		−.18	−.11	+.10	+.02	−.01	+.07	+.04	+.17
	Difference		.02	.07	.13	.08	.01	.03	.06	.01
Circumference fore-flank	157			+.22**	+.02	−.29**	−.27**	+.40**	+.41**	−.10
	62			+.03	+.05	−.26*	−.45**	+.27*	+.38**	−.31*
	Difference			.19	.03	.03	.18	.13	.03	.21
Width of shoulder	157				+.07	−.02	+.07	+.16*	+.05	+.01
	62				+.17	+.24	+.01	−.16	−.26*	−.22
	Difference				.10	.26	.06	.32*	.31*	.23
Length of body	157					−.17*	−.09	+.19*	+.25**	+.13
	62					+.24	+.02	+.14	−.05	−.004
	Difference					.41**	.11	.05	.30*	.13
Average daily gain	157						+.70**	−.14	−.72**	+.05
	62						+.77**	+.05	−.74**	+.07
	Difference						.07	.19	.02	.02
Efficiency	157							−.19*	−.56**	+.10
	62							−.19	−.73**	+.11
	Difference							—	.17	.01
Days to weaning	157								+.65**	−.06
	62								+.61**	−.36**
	Difference								.04	.30*
Days to final weight	157									−.14
	62									−.26*
	Difference									.12

* Significant at 0.05 level.
** Highly significant at 0.01 level.

heavier animal at birth had longer legs and a longer body at 900-pounds live weight. It also tended to be smaller in circumference at the fore-flank and in width of shoulder. This measurement appeared to have no association with days to final weight, average daily gain, and efficiency.

Circumference of fore-flank, which measures bone structure and condition of fleshing, had small significant positive correlations with width of shoulder, days to weaning, and days to final weight, but had a small significant negative correlation with average daily gain and efficiency for 157 animals. The same was true for the group of 62 steers except that there was not a significant correlation for width of shoulder. The difference between the two groups for this correlation was not significant. This result is similar to that found by Lush (1928 and 1932), but is different from that found by Black *et al.* (1938), who did not find significance of fore-flank (heart girth) to be correlated appreciably with rate of efficiency of gain. This difference may have been due to their having steers of widely different breeding in their sample. The results are closely related to the age of the steers as indicated by the significant positive correlations between circumference of fore-flank and days to weaning and final age. Thus younger animals tended to be smaller in circumference of fore-flank.

Width of shoulder, which measures bone structure and condition of fleshing, had no significant associations with any of the measures of performance in either of the two groups except a positive significant correlation with days to weaning for the group of 157 steers and a negative significant correlation with days to final weight for the 62 steers. In these cases there were significant differences between the correlations for the two groups. The relationships were, therefore, of doubtful significance. The results differ from those of Black *et al.* (1938) insofar as the relation between width of shoulder, average daily gain, and efficiency are concerned.

Length of body, which is largely a skeletal measure, had a small negative correlation with average daily gain and small positive correlations with days to weaning and days to final weight for the larger group. No significant correlations were found for the smaller group. The differences between correlations with days to final weight and average daily gain were significant. Black *et al.* (1938) obtained different results. They found efficiency of gain to be highly correlated with length of body as well as with height at withers.

Average daily gain had high positive correlations (0.70 and 0.77) with efficiency and high negative correlations (—0.72 and —0.74) with days to final weight in the groups of 157 and 62 steers respectively.

This is to be expected as the greater the daily gain of an animal the less time will be required to reach the desired weight at slaughter and a smaller amount of feed needed for maintenance and fattening.

Efficiency, too, had high negative correlations (—0.56 and —0.73) with days to final weight for both the groups and small negative correlations with days to weaning. The correlation for 157 steers was significant while that for 62 steers was not, although both were of the same size, —0.19.

Days to weaning was highly correlated in both the groups with days to final weight. This seems reasonable as the earlier the animal reaches 500 pounds (weaning weight) the earlier he will be expected to reach slaughter weight. Days to weaning had a significant negative correlation (—0.36) with birth weight for the group of 62 steers but not for the group of 157 steers. The difference between the correlations for the two groups was significant. It is reasonable to assume that the larger calves at birth would reach weaning weight sooner since they do not need to grow so much and their larger size is probably an indication of greater vigor and ability to grow rapidly. The fact that a similar correlation was not found in the group of 157 steers may be due partly to some of them being weaned at a fixed age rather than a fixed weight. Dawson, Phillips, and Black (1947) found with beef Shorthorn calves that those that were heavier at birth tended to reach weaning weight (500 pounds) and final weight (900 pounds) sooner than lighter calves.

Days to final weight with birth weight had a small significant negative correlation (—0.26) for the group of 62 steers. The correlation was likewise negative for the group of 157 steers but smaller and not significant. One would expect the correlation to be less than that between birth weight and days to weaning weight and to be negative for the reasons given in the preceding paragraph.

In general, the agreement between the correlations for the two groups is quite close, only 5 of the differences out of 45 being significant. This indicates that the differences in treatment received by the steers, in general did not affect markedly the correlations between the measurements and the performance of the steers, although in many instances the differences in treatment were associated with significant differences in the measurements and the performance of the steers. Since the total group (157 steers) has the advantage of the larger number of animals, while the subgroup (62 steers) has the advantage of more uniform treatment, one cannot say definitely which figure should be used where there is a difference. However, it seems reasonable to assume that the true value probably lies between the two values found. Where a choice

must be made the authors are inclined to favor the figures for the 62 steers since the number of animals is reasonably large and the treatment of the steers more uniform.

Summary and Conclusions

Five body measurements—height at withers, height to floor of chest, heart girth, width at shoulders, and length of body—and their relationship to average daily gain, efficiency of feed utilization, and the age at slaughter of Milking Shorthorn steers were studied. The animals were raised and fed in record of performance studies at the U.S.D.A. Research Center, Beltsville, Maryland. Measurements were taken and performance data calculated when the steers reached a live weight of 900 pounds. There was a total of 157 steers. In addition to the total group, which varied somewhat in their treatment, a subgroup of the 157 steers consisting of 62 animals which received more uniform treatment was studied. In general, there was quite close agreement in the correlations between body measurements and the measures of performance for the two groups and also between the measurements themselvs. Conclusions based on results from both groups were:

The steers tended to vary independently with regard to the body dimensions measured as shown by the lack of high correlation between them except for a fairly high association between height at withers and height at floor of chest.

Circumference of fore-flank appears to be the best of the five measurements studied for use in the selection of breeding animals so far as relation to the measures of performance studied is concerned.

Greater width of shoulder at 900 pounds had a slight tendency to be associated with a decrease in height at withers.

Steers with a high average daily gain in general had a high efficiency of feed utilization.

Results supported by data on the group of 157 steers and not opposed by results from the other group indicated that:

1. Steers which are shorter in height and in length of body and smaller in circumference of fore-flank were slightly superior in the production characters studied.

2. Greater width of shoulder at 900 pounds had a slight tendency to be associated with a large heart girth (circumference of fore-flank) and with a decrease in height to floor of chest.

3. Length of body tended to be positively associated with the height measurements but not with circumference of fore-flank.

Results obtained with the group of 62 steers indicated that calves heavier at birth had a tendency to reach weaning weight and final weight at an earlier age than lighter calves.

Literature Cited

Black, W. H., B. Knapp, Jr., and A. C. Cook, 1938. Correlation of body measurements of slaughter steers with rate and efficiency of gain and with certain carcass characteristics. Jour. Agr. Res. 56:465.

Dawson, W. M., R. W. Phillips, and W. H. Black, 1947. Birth weight as a criterion of selection in beef cattle. Journal of Animal Science 6:247.

Fisher, R. A. 1946. Statistical methods for research workers. Oliver and Boyd, Edinburgh: 354 pp.

Hetzer, H. O., O. G. Hankins, J. X. King, and J. H. Zeller, 1950. Relationship between certain body measurements and carcass characteristics in swine. Journal of Animal Science 9:37.

Hultz, F. S., and S. S. Wheeler, 1927. Type in two-year-old beef steers. Wyo. Agr. Exp. Sta. Bul. 155, pp. (127)—148 illus.

Knapp, B., Jr. and A. C. Cook, 1933. A comparison of body measurements of beef and dual-purpose cattle. Amer. Soc. Anim. Prod. Proc. (1932) pp. 77–84.

Lush, J. L. 1928. Changes in body measurements of steers during intensive fattening. Tex. Agr. Exp. Sta. Bul. 385.

Lush, J. L. 1932. The relation of body shape of feeder steers to rate of gain, to dressing percent and to value of dressed carcass. Tex. Agr. Exp. Sta. Bul. 471.

Schmidt, J., and C. von Patow, 1938. Studies on the development of female progeny of the herd of black pied cattle at the exp. and res. farm Kappehof Z. Tierz 4:5.

Severson, B. O., and P. Gerlaugh. 1917a. A statistical study of body weights, gains and measurements of steers during the fattening period. Penn. Agr. Exp. Sta. Annual Report. 1916–17, pp. 275.

Severson, B. O., P. Gerlaugh, and F. L. Bentley. 1917b. Record of body measurements of steers. Penn. Agr. Exp. Sta. Annual Report for 1916–17, pp. 296.

Snedecor, George W. 1948. Statistical methods. Iowa State College, Ames. 485 pp.

Swett, W. W., and R. R. Graves. 1939. Relation between conformation and anatomy of cows of unknown producing ability. Jour. Agr. Res. 58:199.

Wallace, H. A., and G. W. Snedecor, G. W. 1931. Correlation and machine calculation. Iowa State Col. Off. Pub. 30 (4): 71 pp.

GENETIC AND ENVIRONMENTAL CORRELATIONS BETWEEN WEANING SCORES AND SUBSEQUENT GAINS IN THE FEED LOT WITH RECORD OF PERFORMANCE STEERS

BRADFORD KNAPP, JR., AND R. T. CLARK
Bureau of Animal Industry, U. S. Department of Agriculture[1]

IT has been believed by the majority of animal husbandmen for many years that it was possible to observe an animal and from certain observations predict the future gains of that animal in the feed lot. Cattle feeders still buy according to visual observation, selecting a type of animal that they think will make the greatest economic return while on feed. Feeder cattle have been priced according to a grade on the supposition that the better grade animals will return to the cattle feeder greater gains and, thus, greater profit. The advisability of selecting animals of a certain breed type with uniform color and body type has been emphasized. Such beliefs have been handed down from generation to generation. It is the purpose of this paper to present the results of a study of this relationship and show whether such beliefs are founded on fact or not.

Hankins and Burk (1938) reported on a study of 2073 feeder cattle from many experiments. They correlated most of the production and grade factors in cattle and found that there was little or no relationship between feeder grade and subsequent gains of cattle in the feed lot ($r=0.09$). They did find, however, that there was a fairly high correlation between feeder grade and the number of days required to reach a certain slaughter grade and the feeder grade was an index of subsequent slaughter steer grade.

Johnson (1944) reported that there was a correlation of 0.03 between feeder grade of lambs and rate of gain in the feed lot. Patterson *et al.* (1949) reported a correlation of -0.041 between a type score at weaning time and rate of gain in the feed lot. Knapp *et al.* (1941) reported a correlation of 0.025 between score at weaning and subsequent gains in the feed lot with record of performance steers.

Material and Methods

The feeding and management of all calves were the same for any one year. This study is based on 613 steers from 83 Hereford sires in experi-

[1] Contribution from the Bureau of Animal Industry, U.S.D.A. in cooperation with the Montana Agricultural Experiment Station. Paper No. 227 Journal Series.

ments conducted in cooperation between the U. S. Bureau of Animal Industry and the Montana Agricultural Experiment Station.

An adaptation of the method of analysis used by Hazel, Baker and Reinmiller (1943) and later by Knapp and Clark (1947) was employed to analyze these data. For the convenience of the reader, the writers will review the methods as adapted to beef cattle.

A number of factors may affect both gain in weight and score at weaning. Since each source of variation is quantitative or partially so, estimates of each source of variation may be made. Growth of each calf may be divided into two sources of variation: (1) genetic (G), composed of the average effects of all genes affecting growth rate and (2) a residual effect (E), which includes the effects of environment peculiar to each calf plus the effects of any dominance and epistasis among the genes affecting growth. The same is true of score of calf. Thus, growth or score of calf at any point may be expressed as:

$$X=G+E+2\ Cov_{GE}$$

Since the data are on the basis of intra-year and intra-station, there is no reason to suspect a correlation between G and E and it is assumed to be O. The variance of growth or score may be:

$$V_X = V_G + V_E$$

Thus, the covariance between gains and scores would be:

$$CV_X=CV_G+CV_E$$

From these equations, the correlation of either of the effects (G or E) between score and gains may be calculated as follows:

$$r_{G_sG_g}=\frac{CV_{G_sG_g}}{\sqrt{(V_{G_s})(V_{G_g})}}$$

The first step consists in breaking down the intra-year, intra-station variance and covariance into the two mean squares: between sire groups and within sire groups. By the use of the method of Winsor and Clarke (1940) these mean squares may be further analyzed into their two components V_s and V_l. Since this population resulted from the mating of random selected cows (within age groups) to the various sires the genetic variance in V_s is $\frac{1}{4}$ and in V_l is $\frac{3}{4}$. Based on this assumption the genetic and environmental variances and covariances may be calculated as follows:

$$V_G = 4V_s \qquad CV_G = 4CV_s$$
$$V_E = V_l - 3V_s \qquad CV_E = CV_l - 3CV_s$$

The scores were obtained each year at both stations by a three-man committee scoring independently. A. H. Form 522 was used for scoring.

Essentially the same points are scored as for feeder grade and score and feeder grade are essentially the same. The average of the three scores was used as the score for that animal. The scores ranged from 52 to 94 which would be comparable to feeder grades of Common to

TABLE 1. ANALYSIS OF VARIANCE AND COVARIANCE FOR GAINS AND SCORES, INTRA-YEAR AND STATION ANALYSIS

Source of variance	df	Theoretical composition	Score X^2	XY	Gains Y^2
Between sire groups	71	$A + kB^1$	66.86	81.20	6287.51
Within sire group	531	A	41.19	−12.67	2458.84

[1] k, the average number of calves in the sire groups equals 7.39.

TABLE 2. COMPONENTS OF VARIANCES AND COVARIANCES FOR SCORES AND GAINS

Source of variance	Scores X	XY	Gains Y
Sire variance (V_s)	3.47	12.70	518.09
Individual variance (V_i)	41.19	−12.67	2458.84

TABLE 3. GENETIC, ENVIRONMENTAL AND TOTAL OR PHENOTYPIC VARIANCES AND COVARIANCES OF SCORES AND GAINS

Source of variance	Symbol	Scores s	Gains g
Genetic	V_{G_s}	13.88	50.80
Genetic	V_{G_g}		2072.36
Environmental	V_{E_s}	30.78	−50.77
Environmental	V_{E_g}		904.57
Phenotype	V_{X_s}	44.66	+0.03
Phenotype	V_{X_g}		2976.93

Fancy Feeders. The steers were then placed on feed and fed for 224 to 270 days.

Results and Discussion

The results of the analyses of variance and covariance for gains and scores are shown in table 1.

The correlation between scores and gains within sire groups was not significant. In table 2 are shown the components of these variances.

The genetic, environmental and total or phenotypic variances are shown in table 3.

The following genetic and environmental correlations were obtained from the above variance and covariance:

$$v_{G_sG_g} = 0.300$$
$$v_{E_sE_g} = -0.304$$
$$v_{sg} = 0.0001$$

These correlations are shown also with the path-coefficients for each effect in figure 1. These results indicate that there is a very low correlation between scores and gains of the steers. However, there seems to

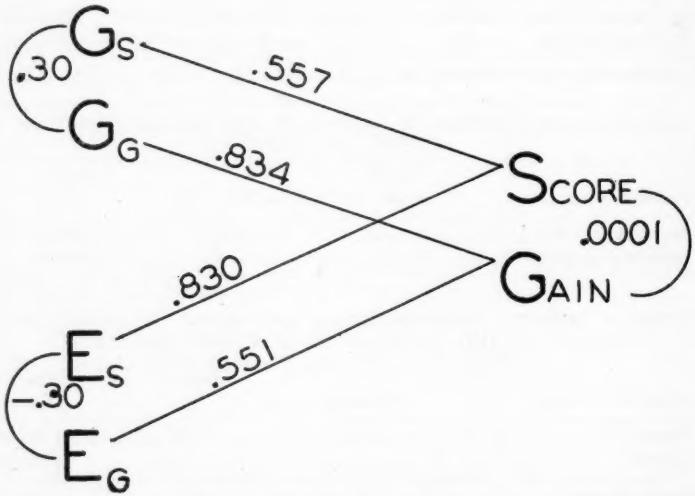


Figure 1. Path-coefficient diagram to show the genetic and environmental influences on score at weaning time (S) and subsequent gains in the feed lot (G).

be a fair correlation between scores and gains from the genetic standpoint. This is counterbalanced by the relatively high negative correlation between the environmental sources of scores and gains. This result would seem to indicate that there are some genetic factors which determine both scores and gains. Heritability estimates of scores and gains would be the square of the path coefficient in each case. For gains the heritability would be 70 percent and for scores it would be 31 percent. In other words, it would seem that though both scores and gains are fairly highly heritable, there is some association between the genetics of scores and the genetics of gains. This association is not observable in gross correlation, or in the phenotype, because of the negative influence of the environmental factors of scores and gains.

The environmental factors influencing gains are probably feed consumption, temperature, and feeding and management practices while the cattle are in the feed lot. Those influencing score at weaning are associated mostly with the maternal influences, such as mothering ability, milk production of dam, and range conditions. There are probably two explanations of this negative relationship between the environmental influences of scores and gains: (1) There may be some compensating increased gain in the feed lot for poor conditions of environment before weaning. It is well known that the condition of the calf has a great influence on the score of the calf at weaning time. (2) Since the hereditary influences are measured by sire variances, then within sire groups the better milking cow may have a poorer heredity for gains. The calf from a good milking cow may have a poorer heredity for gains from his dam and therefore make poorer gains in the feed lot. The calf from the poorer milking dam meanwhile could have received genes for better gains and, thus, do better in the feed lot. These statements are based on the assumption that a negative relationship exists between gains and milk production in cattle.

This lack of gross correlation in some respects works to the advantage of the beef cattle breeder. Since there is little or no gross correlation and relatively low genetic correlation between scores and gains, it is possible for the beef cattle breeder to select, within any type of animal, for greater rate of gain without materially affecting the type or conformation of his herd. Or he may select for both conformation characteristics and rate of gain and make the progress expected, since in selecting for one characteristic he is not unduly influencing the other characteristic.

In any event, it appears that score at weaning time is not an index of subsequent gains in the feed lot. The hereditary influences affecting gains and scores are somewhat related, but these are almost completely nullified by the negative relationship in environmental influences. If this is true, and there is ample evidence from this and other studies that it is true, then the selection of feeder calves for rapid gain by the use of present methods of visual appraisal as a basis is ineffective. Except for the fact that feeder grade or score indicates subsequent slaughter grade and the relative amount of gain required on feed to reach a certain slaughter grade, as shown by Hankins and Burk (1938), it is doubtful that there is any value in selecting feeders on the market. These conclusions, based on this study, and supported by evidence from other studies, are contrary to accepted practice, since many animal husbandmen have believed that they could select for rapidity of gain through visual criteria.

Summary

This analysis is based on 613 steers from 83 Hereford sires in experiments conducted by the United States Bureau of Animal Industry in cooperation with the Montana Agricultural Experiment Station. The variances and covariances of gains and weaning score were broken down into genetic and environmental influences. A gross correlation of 0.0001 was observed between score at weaning and gains in the feed lot. A genetic correlation of 0.300 and an environmental correlation of —0.304 were obtained. The heritability estimate for scores was 31 percent and for gains 70 percent. The negative environmental correlation may be due to (1) some compensating increased gains in the feed lot for the relatively poorer conditions of environment before weaning, or (2) negative correlation that may exist between milk production and gains. It is concluded that there is little value in selecting feeders for rapid gain if sole dependence is placed on visual method of selection.

Literature Cited

Hankins, O. G. and L. B. Burk. 1938. Relationships among production and grade factors of beef. U.S.D.A. Tech. Bul. 665, 39 pp. illus.

Hazel, L. N., M. L. Baker and C. F. Reinmiller. 1943. Genetic and environmental correlations between the growth rates of pigs at different ages. JOURNAL OF ANIMAL SCIENCE 2:118.

Johnson, L. E. 1944. The relationship of feeder grade, initial weight, total gain, finished grade and carcass grade of lambs. JOURNAL OF ANIMAL SCIENCE 3:224.

Knapp, B. Jr., A. L. Baker, J. R. Quesenberry and R. T. Clark. 1941. Record of performance in hereford cattle. Montana Agr. Expt. Station Bul. 397.

Knapp, B. Jr., and R. T. Clark. 1947. Genetic and environmental correlations between growth rates of beef cattle at different ages. JOURNAL OF ANIMAL SCIENCE 6:174.

Patterson, R. E., J. H. Jones, J. J. Bayles and R. V. Turnbough. 1949. Performance testing and progeny testing of beef breeding stock as an aid to selection. JOURNAL OF ANIMAL SCIENCE 8:608. (Abstract)

Winsor, C. P. and G. L. Clarke. 1940. A statistical study of variation in the catch of plankton nets. Journal Marine Res. 3:1.

CORRECTION FACTORS FOR ADJUSTING WEANING WEIGHTS OF RANGE CALVES TO THE CONSTANT AGE OF 190 DAYS[1]

LESLIE E. JOHNSON AND C. A. DINKEL[2]
South Dakota Agricultural Experiment Station

IN experimental beef cattle breeding investigations, it frequently is desirable to have individual weights of the animals at constant ages. This is especially true at weaning age. Some workers have weaned and weighed all calves at a constant age regardless of the work involved. Ages at which such weights have been taken usually have been 196, 200, or 205 days. A few workers have weaned their experimental calves at 500 pounds and made their comparisons on the basis of the rate of gain until reaching that weight. Since birth dates of calves normally have a range of 2 to 3 months each calving season, such methods usually are impractical. This is especially true for cattle maintained on western and north central ranges.

Convenient methods for correcting swine weights to a constant age have been devised by Bywaters and Willham (1935), Whatley and Quaife (1937), and Lush and Kincaid (1943). Phillips and Brier (1940) have developed a similar method for estimating weaning weights of lambs. Koger and Knox (1945) have published a method for estimating weaning weights of range calves at a constant age when all weights are made on a given date. The data for their factors were collected on New Mexico ranges under climatic and management conditions highly different from those existing on South Dakota ranges.

Data and Methods

The data used in this study were the monthly weights taken from birth to weaning on 297 high-grade and purebred Hereford calves. These calves were raised on the range at the Cottonwood Range Field Station, Cottonwood, South Dakota, and represent the 1942–1948 calf crops inclusively. The majority of the calves were born in April and May with a few scattered births in March and June. They were raised

[1] A contribution from the Animal Husbandry Department. Approved for publication by the Director of the South Dakota Agricultural Experiment Station: Publication No. 259 of Journal Series.

[2] Animal Geneticist, Bureau Animal Industry (Formerly Head, Animal Husbandry Department), and Asst. Animal Husbandman respectively.

with their dams on a range consisting of approximately one-third Blue Grama grass, one-third Buffalo grass, and one-third Western Wheat grass. The annual precipitation averaged 14.6 inches per year during the period studied. The calves received no feed other than milk from their dams and grass. They were all weaned as near November first as was possible, and all were weaned the same day. The average weaning age was 185 days and the average weaning weight was 379.7 pounds.

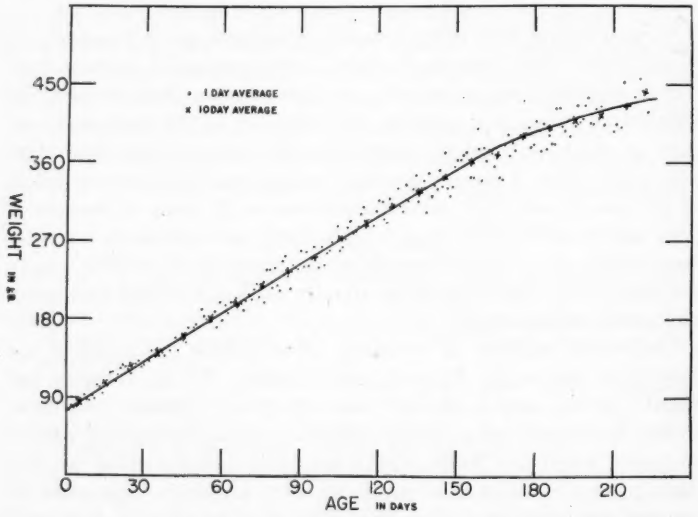


Figure 1. Growth Curve of Hereford Calves from Birth to Weaning at Cottonwood Range Field Station, Cottonwood, South Dakota.

Figure 1 shows the growth curve of the calves studied. The dots represent averages of all weights available for each day of age. The "x's" represent the average weights of all calves weighed within successive 10-day periods. The growth curve was drawn free-hand from an inspection of the data.

The figure rather clearly shows that growth from birth to about 155 days of age is practically an additive effect and, therefore, is represented by a straight line. However, thereafter, growth continues at an apparently diminishing rate.

Thus, although the growth curve is not a straight line at any point from birth to weaning, it is nearly a straight line from birth to 155

days, and from 155 days to 225 days—the maximum weaning age. The problem of adjusting weights to a standard age was, therefore, attacked by calculating 2 sets of linear correction factors using the methods of Bywaters and William (1935) and Whatley and Quaife (1937).

To calculate these age corrections the point of origin of weight on age was first determined by using the intercept of the least squares line of best fit with the age axis. This intercept was then used in the equation: $Y=W\frac{(A-I)}{(X-I)}$ where Y is the corrected weight, W is the actual weight at age X, A is the standard age, I is the intercept, and X is the actual age in days. The standard ages used were 155 days and 190 days.

TABLE 1. GROWTH DATA ON CALVES STUDIED IN TWO PORTIONS OF THE BIRTH TO WEANING GROWTH CURVE

Item	Age Period	
	0 to 154 days	155 to 225 Days
Average Age (Days)	76.8	183.8
Average Weight (Pounds)	217.2	394.5
Regression of Weight on Age	1.85	0.84
Intercept of Weight on Age (Days)	—40.0	—287.0

The 155-day age was chosen for the first age correction because it marked the end of the first approximately straight line portion of the growth curve. The 190-day age was chosen because it was the average weaning age of the calves during the last three years of the experiment studied, and likely will be the weaning age at South Dakota Agricultural Range Experiment Stations in the future.

Table 1 gives the average age, weight, regression coefficients, and intercept of weight on age for the data studied.

In order to facilitate the correction of numerous weights, multiplicative factors were calculated for correcting weights at all ages to the two standard ages. These factors are simply, $\frac{\text{Standard age}-\text{Intercept}}{\text{Actual age}\quad-\text{Intercept}}$ and are given in tables 2 and 3. Thus, to correct the weaning weight of any calf from a given age to the standard age of 190 days, one needs only to multiply the actual weight by the factor shown in table 3 if the calves are between 155 and 225 days of age. If they are younger than 155 days, one needs first to correct the weight to 155 days (table 2) and then to 190 days of age (table 3).

Another set of correction factors was developed for the data by employing the method used by Lush and Kincaid (1945). These correction factors were made only for the period of 155 to 225 days of age. The method employs a quadratic equation. The quadratic equation used is obtained by setting up the first derivative and integrating. The basic assumption in this method is that the decrease in rate of gain is constant over the period, whereas in the first method the rate of gain

TABLE 2. CORRECTION FACTORS FOR ADJUSTING WEIGHTS OF RANGE CALVES TO A STANDARD AGE OF 155 DAYS—LINEAR METHOD

AGE	C.F.	AGE	C.F.
120	1.22	138	1.10
121	1.21	139	1.09
122	1.20	140	1.08
123	1.20	141	1.08
124	1.19	142	1.07
125	1.18	143	1.07
126	1.17	144	1.06
127	1.17	145	1.05
128	1.16	146	1.05
129	1.15	147	1.04
130	1.15	148	1.04
131	1.14	149	1.03
132	1.13	150	1.03
133	1.13	151	1.02
134	1.12	152	1.02
135	1.11	153	1.01
136	1.11	154	1.01
137	1.10	155	1.00

is assumed constant. The following data were taken from the average growth curve for use in the estimating equation: Average growth rate at 155 days of age was 1.7 pounds per day, average growth rate at 225 days was 0.7 pound per day, and the average weight at 190 days was 403.4 pounds. Under the above assumptions the following proportion results:

$$\frac{Y-0.7}{X-225}=\frac{0.7-1.7}{225-155}$$

where Y is daily gain in pounds and X is age in days. Solving for Y we have:

$$Y=3.914283-0.0142857X=\frac{dW}{dX}$$

where W is weight in pounds and X is age in days. Integrating this and solving for the constant by substituting W=403.4 when X=190 gives:

$$W=3.914283X-0.00714285X^2-82.45689$$

TABLE 3. CORRECTION FACTORS FOR ADJUSTING WEIGHTS OF RANGE CALVES TO A STANDARD AGE OF 190 DAYS—LINEAR AND QUADRATIC METHODS

Age	Correction Factor		Age	Correction Factor	
	Linear	Quadratic		Linear	Quadratic
155	1.079	1.143	190	1.000	1.000
156	1.076	1.138	191	0.997	0.997
157	1.074	1.133	192	0.995	0.994
158	1.071	1.127	193	0.993	0.991
159	1.069	1.122	194	0.991	0.988
160	1.067	1.117	195	0.989	0.985
161	1.064	1.112	196	0.987	0.983
162	1.062	1.107	197	0.985	0.980
163	1.060	1.102	198	0.983	0.977
164	1.057	1.100	199	0.981	0.975
165	1.055	1.093	200	0.979	0.972
166	1.053	1.088	201	0.977	0.970
167	1.050	1.084	202	0.975	0.967
168	1.048	1.079	203	0.973	0.965
169	1.046	1.075	204	0.971	0.963
170	1.043	1.071	205	0.969	0.961
171	1.041	1.067	206	0.967	0.958
172	1.039	1.063	207	0.965	0.956
173	1.037	1.059	208	0.963	0.954
174	1.034	1.055	209	0.961	0.952
175	1.032	1.051	210	0.959	0.950
176	1.030	1.047	211	0.957	0.948
177	1.028	1.043	212	0.955	0.946
178	1.025	1.039	213	0.954	0.944
179	1.023	1.036	214	0.952	0.942
180	1.021	1.032	215	0.950	0.940
181	1.019	1.029	216	0.948	0.938
182	1.017	1.025	217	0.946	0.936
183	1.014	1.022	218	0.944	0.935
184	1.012	1.018	219	0.942	0.933
185	1.010	1.015	220	0.940	0.931
186	1.008	1.012	221	0.939	0.929
187	1.006	1.009	222	0.937	0.928
188	1.004	1.006	223	0.935	0.926
189	1.002	1.003	224	0.933	0.925
			225	0.931	0.923

The equation for adjusting weights to an age of 190 days is:

$$W = Z \left[\frac{403.4}{3.914283X - 0.00714285X^2 - 82.45689} \right]$$

where Z is actual weight at age X.

Table 3 (column labeled "quadratic") gives in a convenient form the numerical values for the term within the above bracket for adjusting weights taken between 155 days and 225 days of age to the standard age of 190 days.

Comparison of the Two Methods

The accuracy of the two sets of factors was compared by studying the weights on 70 calves drawn at random from the data. Each of these calves had a weight made on or about 190 days of age. All had weights taken 30 days prior to the standard age period and many had weights taken 30 days following the standard age.

For the linear correction factors the estimated weaning weight was 4.2 pounds less than the actual weaning weight, with a standard error of estimate of 11.2 pounds. For the quadratic correction factors the estimated weaning weight was 11.0 pounds greater than the actual weaning weight, with a standard error of estimate of 11.9 pounds. On the basis of deviations regardless of signs, the linear factors resulted in an average deviation from actual weights of 13.3 pounds, which is not greatly different from that found when weighing calves on successive days. Similarly, the quadratic factors resulted in an average deviation of 17.2 pounds.

Discussion

The findings indicate that calves nursing cows on the range have similar growth curves. The growth curves at or near weaning age are constant enough to allow weaning and weighing of calves on a given date and correcting weights to a standard age without much loss of information. Correction factors developed from a linear equation were slightly more accurate than those developed from a quadratic equation and therefore are recommended.

Caution should be used in applying the factors to calves raised under different feeding and management practices than those to which the calves used in this study were subjected. Also, it would seem unwise to follow management practices that would cause calves to be weighed much more than 30 days from the standard age desired. Factors are given which allow correcting 120-day weights to the standard age of 190 days; however, it is obvious that many conditions might alter

subsequent growth in individuals. Thus, the correction factors given should be used only where it is absolutely necessary and then they should be interpreted with caution.

Summary

Monthly weights on 297 beef calves were studied to obtain the growth curve from birth to weaning and to calculate correction factors for adjusting weaning weights of range calves to a standard age. The data showed that the growth curve of South Dakota range calves approximated a straight line up to 155 days of age, and thereafter increased at a decreasing rate. A set of linear correction factors was developed to adjust weights taken between 120 and 155 days up to a standard age of 155 days. Two sets of factors were developed for the period 155 to 225 days of age which correct weights to the standard age of 190 days. These two sets differed in the method of calculation. Both sets were accurate enough to be highly useful, but the set based on the linear equation appeared to be the more accurate and therefore is recommended. Caution should be practiced in applying the factors to calves raised under different climatic or management conditions or to calves where the weaning weight has been taken much more than 30 days preceding or following the standard weaning age.

Literature Cited

Bywaters, J. H. and O. S. Willham. 1935. A method comparing growthiness of pigs weighed at different ages and subjected to different treatments. Amer. Soc. Anim. Prod. Proc. 28:116.

Koger, Marvin and J. H. Knox. 1945. A method for estimating weaning weights of range calves at a constant age. JOURNAL OF ANIMAL SCIENCE 4:285.

Lush, Jay L. and C. M. Kincaid. 1943. Adjusting weights of pigs to an age of 154 days. Research Item No. 25, Regional Swine Breeding Laboratory, Ames, Iowa.

Phillips, Ralph W. and C. W. Brier. 1940. Estimating weights of lambs at a constant age. U.S.D.A. Circ. No. 541.

Whatley, J. A. and E. L. Quaife. 1937. Adjusting weights of pigs to a standard age of 56 days. Amer. Soc. Anim. Prod. Proc. 30:126.

A STUDY OF CLASSIFICATION SCORES OF HEREFORD COWS[1]

WARREN GIFFORD, C. J. BROWN, AND M. L. RAY
University of Arkansas[2]

CONFORMATION-DIFFERENCES among our beef animals have long been made by mental comparisons and subjective scoring methods. However, there have been very few studies reported in the literature concerning the use of this most common means of evaluation.

As a part of a more extensive study[3] of beef cattle performance all animals in the Arkansas Agricultural Experiment Station Hereford herd have been classified semi-annually since 1940. Classifications were made by two or more judges according to a score card designed to compare each animal subjectively with the breed average.

The purpose of the present study was to secure information on (1) the agreement between judges (2) the repeatability of judges, and (3) the cause of variation in conformation scores.

Methods and Materials

A description of the methods of scoring used in this study was given by Ray and Gifford (1949). There were seven divisions of the score card which correspond to a description and a numerical value as follows: 100–90, Excellent; 90–80, Very Good; 80–70, Good Plus; 70–60, Good; 60–50, Good Minus; 50–40, Fair; 40–30, Poor. The division of the score card corresponding to Good was designated to represent the breed average. Each animal was scored for the following items of conformation: breed type, general appearance, head and neck, fore quarters, body, hind quarters, and overall rating.

The cattle were scored once in the winter and once in the summer at a time which would correspond roughly to the middle of the summer grazing and winter feeding seasons. During the period of this study, from 1940–49, 187 different animals have been scored. Some animals have been scored as many as eighteen times.

[1] Research paper 1010 Journal Series, University of Arkansas. Published with the permission of the director of the Arkansas Agricultural Experiment Station.

[2] The Animal Industry Department, University of Arkansas, acknowledgment is gratefully made for the assistance of N. W. Hilston and A. L. Neumann formerly staff members in Animal Industry.

[3] Since 1948 the study has been in cooperation with the Southern Agricultural Experiment Stations, Regional Project S-10, and with the Bureau of Animal Industry, U.S.D.A.

At the time of classification each judge worked independently of all other judges and without access to the previous scores of the animals. During the period of the study thirteen different judges have scored the cattle, however, only one judge (Judge A) scored all cattle on

TABLE 1. WITHIN SEASON CORRELATIONS BETWEEN JUDGES*

Season	General Appearance	Fore Quarters	Body	Head & Neck	Hind Quarters	Breed Type	Overall Rating	Number of Animals
Judges A and B:								
October '40	.92	.80	.89	.69	.81	.86	.97	27
January '41	.74	.76	.79	.79	.73	.78	.84	45
June '41	.86	.78	.87	.74	.83	.86	.91	66
July '41	.83	.82	.88	.69	.84	.88	.94	33
August '43	.83	.83	.83	.82	.79	.89	.96	72
January '44	.76	.67	.68	.68	.69	.70	.71	80
August '44	.82	.66	.78	.76	.73	.78	.76	71
March '45	.73	.74	.72	.57	.66	.65	.68	53
July '45	.77	.78	.76	.71	.76	.73	.74	56
Intra-Season	.80	.75	.79	.73	.78	.80	.87	503
Judges A and C:								
January '46	.81	.61	.75	.70	.65	.82	.85	52
July '46	.51	.48	.68	.62	.68	.72	.73	61
March '47	.68	.41	.67	.64	.45	.58	.72	49
August '47	.69	.59	.78	.75	.51	.72	.87	33
August '49	.76	.58	.58	.58	.48	.81	.78	55
Intra-Season	.74	.52	.69	.67	.56	.73	.78	250
Judges A and D:								
March '47	.69	.64	.74	.74	.57	.69	.96	49
March '48	.77	.54	.56	.67	.49	.68	.74	40
Octoer '48	.75	.77	.78	.76	.68	.84	.84	40
August '49	.91	.65	.72	.62	.73	.73	.80	55
Intra-Season	.78	.64	.70	.67	.62	.73	.82	184
Intra-Judge	.80	.70	.76	.70	.72	.78	.83	937

* All correlations are significant at 1% level.

every classification date. Only four judges scored the cattle more than twice; the scores which these four judges gave females of all ages were analyzed.

Within-season correlations were used to measure the agreement between judges. The repeatability of the judges were calculated by the method of Lush (1938). Analysis of variance, Snedecor (1946), was used to study the variation of the conformation scores.

Results and Discussion

Agreement between Judges

Within-season correlations between the scores of Judge A and Judges B, C, and D, for the seven items of classification are given in table 1. The magnitude of these correlations would indicate that the judges were in general agreement on the points of conformation scored. In general the correlation between judges' ratings was highest for overall rating, followed by general appearance, breed type, body, hind quarters, and fore quarters in that order. The ranking of the items scored in that order would indicate that there was a tendency for judges to agree more closely on the items for which they must consider the entire animal. These results are in agreement with those of Knapp *et al.* (1939) and are to be expected since random scoring errors made on specific items of conformation should tend to cancel when considering the entire animal, thus reducing the random errors in the overall rating.

Repeatability of Judges

The repeatability of a judge would be measured by the correlation between the scores which he would give to the same animal on different classification dates. The repeatability of Judges A, B, and C were calculated using the scores of all animals classified more than three times. The repeatability, mean score, and standard deviation of each of the judges' scores are given in table 2.

The repeatability of the judges in this study is somewhat lower than that found for official judges of the Ayrshire (0.82 and 0.62) and Holstein (0.56) breeds. (Hyatt and Tyler, 1948; Johnson and Lush, 1942). It is possible that these differences might be explained by differences in the training and classification experiences among judges. In the official dairy classification program highly efficient and well trained judges are selected and given special training in breed type schools. Such training would increase the repeatability among judges classification scores. No attempt was made to standardize the ideals of the judges in this study, however, the judges were considered competent experienced beef cattle judges.

From table 2, it may be seen that the average scores of all three judges were approximately the same, however, the standard deviation of the scores of Judge C was much the smallest. This would indicate that the range of the scores of Judge C was narrow in comparison to the other judges which might be explained by him being less critical of

specific defects or more reluctant to give a high score to the better animals.

A comparison of the magnitude of the correlations in table 1 and table 2, show that on the same cows judges were able to agree more

TABLE 2. REPEATABILITY OF SAME JUDGE ON SAME COW

Item	Symbol[1]	Judge A	Judge B	Judge C
Number Animals		87	48	36
Overall-rating	r	.41	.42	.50
	s	9.7	9.5	5.0
	$\bar{x}$	69.3	68.1	69.3
General Appearance	r	.47	.42	.48
	s	9.8	10.1	4.9
	$\bar{x}$	69.1	68.1	69.3
Fore Quarters	r	.57	.39	.16
	s	8.9	8.6	5.0
	$\bar{x}$	70.4	70.0	68.4
Hind Quarters	r	.47	.43	.32
	s	9.4	8.9	5.8
	$\bar{x}$	69.4	68.7	69.3
Body	r	.48	.45	.31
	s	9.4	9.2	6.2
	$\bar{x}$	69.6	69.0	69.3
Head & Neck	r	.49	.58	.53
	s	9.6	8.5	6.3
	$\bar{x}$	69.4	68.2	68.2
Breed Type	r	.42	.45	.55
	s	9.3	9.5	5.2
	$\bar{x}$	69.3	68.7	69.5

[1] r—repeatability of judge on animals scored more than three times.
s—standard deviation of scores.
$\bar{x}$—mean score.

closely with one another on a particular classification date than they were able to agree with their previous scores. Since no information was available to the judges concerning the cow prior to scoring it is to be expected that such temporary conditions as stage of lactation, stage of pregnancy, or age of cow would tend to lower the repeatability of scores on different dates of classification. It is interesting to note, however, that all judges seemed to be affected in roughly the same manner

and of the judges studied none seemed to be able to take the effect of these temporary conditions into proper account.

Variation in Conformation Scores

To study variation in the conformation scores, the scores of each of the other three judges were analyzed separately with the scores of Judge A by analysis of variance for all items of classification. In each analysis only the scores of cows which were classified in all seasons by

TABLE 3. ANALYSIS OF VARIANCE FOR OVERALL RATING FOR 26 COWS WHICH WERE CLASSIFIED IN 4 SEASONS BY EACH OF TWO MEN

Judge A vs. B

Source of Variation	D/F	Mean Squares	Composition of Mean Squares	
Judges	1	4.92	G + 26E + 4D + 104A	A = −.36
Cows	25	432.03**	G + 2F + 4D + 8B	B = 46.21
Seasons	3	535.03**	G + 26E + 2F + 52C	C = 9.29
J x C	25	33.95	G + 4D	D = 4.86
J x S	3	23.42	G + 26E	E = .34
C x S	75	42.88**	G + 2F	F = 14.18
J x C x S	75	14.51	G	G = 14.51
Total	207			

** Significant at 1% level.

A—Variance due to differences between Judges
B— " " " " " Cows
C— " " " " " Seasons
D—Variance due to the interaction between Judges & Cows
E— " " " " " " Judges & Seasons
F— " " " " " " Cows & Seasons
G—Variance unaccounted for in the other components

both judges were used. This restriction of the data was made so that the subclass numbers in the analyses would be equal. In table 3 is given an example of the analysis of one of the items of classification (overall rating) as given by Judge A and Judge B. In table 4 the variance components of these analyses are presented.

An inspection of table 4 will show that for most of the items scored there was no difference in the scoring levels of Judges A, B, and D, but that the scoring level of Judge C was significantly different from that of Judge A. However, these differences in opinion contributed only a small percentage to the total variation of the scores.

Differences between cows (B) were by far the most important source of variation in these data. The mean squares for cows were significant for all items in all the analyses. Cow differences, as a source of variation, were of more importance in the scores of overall rating and of less importance in the scores of fore quarters than in the scores of any of

the other items studied. Cow differences accounted for about 53 percent of the total variation in scores of overall rating and about 43 percent of the total variation in the scores of fore quarters.

There were generally highly significant differences in seasonal scoring levels (C). The reason for these differences might be explained by

TABLE 4. VARIANCE COMPONENTS FOR THE ITEMS OF CLASSIFICATION

Items	Variance Components						
	A	B	C	D	E	F	G
Judge A vs. B							
Degrees of Freedom	1	25	3	25	3	75	75
Overall-Rating	−.36	46.21**	9.29**	4.86	.34	14.18**	14.51
General Appearance	−.64	49.09**	11.11**	7.02**	.86	22.27**	16.98
Fore Quarters	−.69	42.81**	7.12**	8.61**	.91*	16.77**	13.56
Hind Quarters	−.33	47.18**	5.71**	1.90	.14	8.98**	27.85
Body	−.29	41.99**	8.49**	3.27*	.03	15.12**	19.04
Head & Neck	.93	49.28**	47.95*	6.39**	21.46**	9.63**	20.41
Breed Type	−.60	48.33**	9.85	6.07**	.82	12.19**	16.82
Judge A vs. C							
Degrees of Freedom	1	27	2	27	2	54	54
Overall-Rating	1.54**	16.74**	1.21**	.45	−.11	6.43**	5.67
General Appearance	.99	14.73**	3.06**	1.84*	.59*	5.43**	6.50
Fore Quarters	5.35**	11.54**	2.07*	1.72	.81*	5.53**	9.35
Hind Quarters	3.08*	13.18**	−.41	2.94	1.04	5.08*	16.07
Body	2.02**	13.82**	.82	1.43	−.08	12.52**	10.58
Head & Neck	1.44**	21.45**	2.76**	1.21	−.28	7.32**	10.24
Breed Type	.33	14.52**	2.29*	2.36*	.72*	5.94**	8.55
Judge A vs. D							
Degrees of Freedom	1	18	3	18	3	54	54
Overall-Rating	−.27	27.48**	1.36*	2.38*	.22	8.98**	8.38
General Appearance	.26**	21.18**	3.36**	.58	−.53	8.19**	12.65
Fore Quarters	.89	21.12**	.43	2.27	.12	5.47**	12.46
Hind Quarters	2.49**	21.85**	2.05**	4.91**	−.59	6.13*	15.66
Body	−.20	32.16**	.46	1.95	−.07	9.58**	13.61
Head & Neck	−.33	39.21**	3.56**	6.98**	−.37	8.07**	16.08
Breed Type	.79**	29.60**	1.61**	−.12	−.62	7.26**	13.06

* Significant at 1% level.
** Significant at 5% level.

normal changes in condition of the cows since scoring dates were both in winter and summer. The variance associated with these seasonal differences in scores accounted for less than ten percent of the total variation.

The interaction between judges and cows (D) expresses those differences between total scores given the same cow by different judges. The significance of this term did not seem to follow a definite trend but does indicate, that there were some differences in opinion between judges regarding specific cows. This interaction of judges and cows

however, was of minor importance, generally accounting for less than five percent of the total variation.

The interaction between judges and seasons (E) was generally not significant. This would indicate that the judges maintained the same general scoring level relative to each other on the different classification dates.

The interaction between cows and season (F) was the largest of the interaction terms and accounted for between ten and thirty percent of the total variation. This interaction was highly significant in most cases and again points out that the judges were unable to evaluate correctly those temporary environmental conditions which influence the score. Differences in total score which individual cows would receive at different classification dates would be expressed by this interaction. Several of the normal processes of production such as the health of the cow, the changes which occur during gestation and lactation, growth or age changes would be expressed by this term. Since it was one of the greatest sources of variation in the scores it would seem that further study of those temporary conditions which might be responsible are needed.

The interaction of judges and cows and seasons (G) expresses those differences in scores which were not accounted for by differences between judges scoring levels, differences between cows, differences between seasonal scoring levels, or by the interaction of any two of these. This unaccounted-for variance contributed from fifteen to forty percent of the total variation in scores. This interaction would express any random errors along with errors such as those caused by clumsiness in the use of the scorecard or uncertainty among the judges as to what constitutes an average animal. It would seem that standardization of the judges ideals in some manner such as type schools or the use of the average scores of a committee of judges might be effective in reducing this unaccounted-for variance.

Summary and Conclusions

Subjective conformation scores of individual Hereford cows as given by four judges were analyzed to determine the agreement between judges, the repeatability of a judge on the same cow at different scoring dates, and to study the variation in scores of seven items of conformation.

Within-season correlations indicate that judges were in general agreement on the points of conformation scored. Judges seemed to agree more closely for items on which they must consider the entire animal.

Judges were best able to recognize differences in overall-rating and least able to recognize differences in fore quarters.

The correlations between repeated scores of a cow by the same judge were generally between 0.4 and 0.5 using this method of classification.

Judges were able to agree more closely with one another on a particular classification date than they were able to agree with their previous scores.

Although significant differences in judges scores existed, they were of minor importance in determining the total variance in conformation scores.

Cow differences was by far the greatest source of variation in conformation scores. These differences accounted for roughly fifty percent of the total variation.

Seasonal differences in scoring level and the interaction of cows with season were important sources of variation in these data indicating a need for more careful consideration of temporary environmental conditions in the evaluation of our beef animals.

Literature Cited

Hyatt, George Jr., and W. J. Tyler. 1948. Variations in type ratings of individual cows. Jour. Dairy Sci. 31:71.

Johnson, L. E., and J. L. Lush. 1942. Repeatability of type ratings in dairy cattle. Jour. Dairy Sci. 25:45.

Knapp, B. Jr., W. H. Black, and R. W. Phillips. 1939. A study of the accuracy of scoring certain characters in beef cattle. Amer. Soc. of Ani. Prod. pp. 122–124.

Lush, J. L. 1938. Repeatability of scores made by the same man. Reg. Swine Br. Lab. Res. Item No. 6. (Unpublished)

Ray, Maurice L. and Warren Gifford. 1949. A subjective method of evaluating breeding animals in beef herds. JOURNAL OF ANIMAL SCIENCE 8:608.

Snedecor, G. W. 1946. Statistical methods, 4th ed., Collegiate Press, Inc., Ames, Iowa.

RELATIONSHIPS OF FIVE BODY MEASUREMENTS TO SLAUGHTER GRADE, CARCASS GRADE, AND DRESSING PERCENTAGE IN MILKING SHORTHORN STEERS

A. C. Cook,[1] M. L. Kohli,[2] and W. M. Dawson[1]

U. S. Department of Agriculture

In connection with the record of performance work carried out at the U.S.D.A. Research Center, Beltsville, Maryland, various body measurements of each steer were taken at a live weight of approximately 900 pounds. This work was undertaken to determine whether any association existed between body measurements and the slaughter grade, carcass grade, and dressing percentage of the steers. If such relationships exist they would be of practical value to the breeder in the selection of his stock. This study is based on the following measurements: height at withers, height at floor of chest, circumference of foreflank, width of shoulder, and length of body. In addition some consideration is given to the relationships between the performance characters mentioned above as well as average daily gain and efficiency of gain studied in a previous paper, Kohli *et al.* (1951).

Black *et al.* (1938) in a study of 50 animals of beef, dual-purpose and dairy breeding, found that slaughter grade was a better measure of beef type than any ratio of measurements. Therefore, they suggest that measurements should not replace but should supplement reliable slaughter grades. Hankins *et al.* (1938) observed that the rate of gain does not have an important bearing on carcass grade, the correlation being 0.37. Feeder cattle grade and total gain had important and approximately equal influences on carcass grade. Lush (1932) found that the correlations between measurements of feeder steers and their subsequent gains and dressing percentage and the values of dressed beef were low but statistically significant. He indicated that the most important measurements for high dressing percentage were a large heart girth in connection with a shallow chest, a wide loin and large flank girth, a

[1] Animal Husbandman, U. S. Department of Agriculture.

[2] Guest Research Worker from the Civil Veterinary Department, Punjab, India. Acknowledgement—The authors wish to acknowledge the help of Dr. R. G. Schott, Bureau of Animal Industry, in reading and criticizing the manuscript. For cooperation in grading the cattle and carcasses, acknowledgement is also made to L. B. Burk (retired), C. E. Murphy, and M. T. Foster (transferred to Office of Foreign Agricultural Relations) of the Livestock Branch, Production and Marketing Administration, and to R. L. Hiner and M. W. Hazen of the Bureau of Animal Industry. Mr. Hiner also supervised the slaughtering of the cattle and determination of the dressing percentages.

heavy initial weight, small paunch girth, head narrow at the eyes, and short height over hips.

Material and Methods

The data used in this study were taken from 157 Milking Shorthorn steers bred and raised at the Beltsville research station, from 1932 to 1949, as reported by Kohli *et al.* (1951). These steers were all fed individually in a record of performance test to a final weight of 900 pounds. Body measurements were taken just before slaughter. Ninety-one of the first calves were hand-fed milk and the rest were nursed. During the record of performance feeding period from 500 to 900 pounds' live weight, the concentrates fed were as follows: 35 calves got only corn (No. 2 cracked yellow corn) with an average total digestible nutrients (T.D.N.) of 80.6 percent; 26 received corn and varying proportions of a mixture (wheat, oats, linseed meal, bran and corn); and 96 a mixture consisting of cracked yellow corn (5 parts), ground oats (3 parts), wheat bran (1 part) and linseed meal, 37 percent protein (1 part) by weight with a T.D.N. of 75.5 percent and a total digestible protein of 10.57 percent. No. 2 leafy alfalfa hay was given all steers on the record of performance test at the rate of approximately 1 pound of hay to every 2 pounds of concentrate. Concentrate was full fed but in quantity that the animals would clean up readily. None of the animals had access to pasture.

Since all 157 steers were not treated alike with regard to method of suckling, weight at weaning, and ration used for fattening, the steers raised in the last part of the experimental period were also studied separately. These 62 steers, a subdivision of the 157 steers, were all nursed until they weighed approximately 500 pounds and were fed the same ration during the fattening period. This division of the animals permitted determination of the relationships with these variables constant. Differences regarding the year and sire could not be controlled in this way but were studied by analyses of variance in both groupings.

Slaughter grade and carcass grade were the average of scores made independently by three members of a committee who were familiar with the standard market grades of steers as adopted by the U.S.D.A. The carcasses were graded after cooling for 72 hours. Dressing percentages were determined from the live weights taken immediately before slaughter and from the carcass weights after chilling 72 hours.

The methods used for the study of correlation coefficients and analyses of variance were those described by Fisher (1946), Snedecor (1948), and Wallace and Snedecor (1931).

TABLE 1. MEANS AND STANDARD DEVIATIONS FOR SLAUGHTER AND CARCASS GRADES AND DRESSING PERCENTAGE

Items studied	Means		Standard deviation		Differences between means
	157 steers	62 steers	157 steers	62 steers	
Slaughter grade	66.19	66.95	3.46	3.06	0.76
Carcass grade	66.55	68.27	3.47	2.81	1.72**
Dressing percentage	58.57	59.86	2.19	2.02	1.29**

** Highly significant at 0.01 level.

Results and Discussion

The means and differences between the means for slaughter grade, carcass grade, and dressing percentage (table 1) indicate that the 62 steers were superior in all these characteristics to the average of the entire group of 157 steers. The differences for carcass grade and dressing percentage were highly significant. These seem to be the result of the better environment under which this group was raised, but may have been partly due to an improvement in inheritance as the result of the selection of better breeding animals.

Analyses of variance (table 2) show that rations had a significant effect on slaughter grade and dressing percentage. Also the method of suckling the calves significantly affected the slaughter grade, carcass grade, and dressing percentage. Because of the lack of sufficient numbers in the subgroups, the effects of the years, both before and after

TABLE 2. MEAN SQUARES FOR SLAUGHTER GRADE, CARCASS GRADE, AND DRESSING PERCENTAGE OF 157 STEERS[1]

Source of variation	Degrees of freedom	Mean squares		
		Slaughter grade	Carcass grade	Dressing percentage
Between rations within hand-fed and nursed steers	4	29.65*	4.52	15.72**
Between hand-fed and nursed steers within ration	3	68.70**	10.87**	12.3*
Within	151	11.11	9.97	3.54
Total	156			

[1] This table is a condensation of two analyses for each character studied. The variance between hand-fed and nursed steers and between rations has not been included in the table.

* Significant at 0.05 level.

** Highly significant at 0.01 level.

weaning, could not be ascertained when studied along with the effects of methods of feeding. Kohli *et al.* (1951), working with the same steers, indicated that those that were nursed as calves instead of being hand fed milk and those that were fed a mixed concentrate instead of corn, either for the whole feeding period or part of it, were slightly smaller in all five of the body measurements at 900 pounds' body weight, although they gained slightly faster and more efficiently than the other steers.

TABLE 3. MEANS OF THE SLAUGHTER GRADE, CARCASS GRADE, AND DRESSING PERCENTAGE FOR THE HAND-FED AND NURSED CALVES AND FOR THE RATIONS FED TO DIFFERENT NUMBERS OF STEERS

Environmental factors	No. of steers	Means		
		Slaughter grade	Carcass grade	Dressing percentage
(Suckling period)				
Hand-fed	91	65.54	65.22	57.74
Nursed[1]	66	67.09	68.39	59.77
(Feeding period)				
Corn	35	66.09	65.57	57.08
Corn and mixture	26	66.58	65.81	57.50
Mixture	96	66.12	67.11	59.40
Total	157	66.19	66.55	58.57

[1] Only 62 of these were fed the same ration during the fattening period.

Calves that were nursed had on the average slightly better slaughter grades, carcass grades, and dressing percentages than those hand fed milk prior to weaning (table 3). Also steers that received the mixed concentrate during the entire fattening period had better carcass grades and dressing percentages than those fed corn alone for either all or part of the same period.

Most of the correlations between the five body measurements and slaughter grade, carcass grade, and dressing percentage were not high enough to be of much predictive value (table 4). However a considerable number were high enough to be of some selective value in a long-time breeding program. Of these 15 correlations for the group of 157 steers, 12 were high enough to be significant. Most of the correlations for the group of 62 steers were lower than those for the 157 steers and only one was large enough to be significant. The differences between the correlation coefficients for the 157 and 62 steers were large enough to be significant in some cases. The reasons for these significant differ-

ences in some cases and not in others are not clear to the authors although the control of some of the causes of variation would be expected to affect the size of the correlations.

Height at withers, which is almost entirely a skeletal measurement, had significant negative correlations with slaughter grade, carcass grade,

TABLE 4. SIMPLE COEFFICIENTS OF CORRELATION BETWEEN DIFFERENT ITEMS FOR TWO GROUPS OF STEERS

Item studied	Number of steers	Slaughter grade	Difference in slaughter grade	Carcass grade	Difference in carcass grade	Dressing percentage	Difference in dressing percentage
Height at withers	157	−.40**		−.42**		−.20**	
	62	−.19	.21	−.06	.36*	+.06	.26
Height at floor of chest	157	−.51**		−.46**		−.18*	
	62	−.04	.47**	−.21	.25	−.05	.13
Circumference fore-flank	157	+.26**		+.09		−.02	
	62	+.15	.11	+.12	.03	+.43**	.45**
Width of shoulder	157	+.16*		+.16*		+.08	
	62	−.08	.24	+.01	.15	+.16	.08
Length of body	157	−.16*		−.21**		−.20**	
	62	+.02	.18	+.16	.37*	+.20	.40**
Average daily gain	157	+.15		+.17*		+.21**	
	62	+.34**	.19	+.31*	.13	+.03	.18
Efficiency	157	+.14		+.05		−.15	
	62	+.14	..	+.04	.01	−.36**	.21
Slaughter grade	157			+.69**		+.25**	
	62			+.71**	.02	+.27*	.02
Carcass grade	157					+.45**	
	62					+.55**	.10

* Significant at 0.05 level.
** Highly significant at 0.01 level.

and dressing percentage for the 157 steers. The group of 62 steers did not have significant correlations between height at withers and any of these characters. The negative relationships indicate that the slaughter grade as well as the carcass grade tends to be better in shorter than in taller steers.

Height at floor of chest, which also measured a portion of the height of the animal, had similar correlations to those for height at withers, except that there was a highly significant difference in the correlation coefficients with slaughter grade for the two groups.

Circumference of fore-flank, which measures bone structure and condition of fleshing, had a significant positive correlation only with slaughter grade for the group of 157 steers. This correlation, although not very high (0.26), was a slight indication that a steer with a larger heart girth graded higher at time of slaughter. There was a significant difference between the two groups of steers in the correlation between circumference of fore-flank and dressing percentage.

Width of shoulder, which also measures bone structure and condition of fleshing, was significantly and positively correlated with slaughter grade and carcass grade for the group of 157 steers. Width of shoulder was not significantly correlated with dressing percentage as found by Black *et al.* (1938).

Length of body, which is largely a skeletal measure, had low significant negative correlations with all three characters for the group of 157 steers. There were significant differences between the groups in the correlations of length of body with carcass grade and dressing percentage. Since the correlations are positive for the 62 steers and negative for the 157 steers little can be concluded from them.

Average daily gain for the 157 steers had low significant positive correlations with carcass grade and dressing percentage and, for the 62 steers, slightly higher significant positive correlations with slaughter grade and carcass grade. As no significant differences were found between these correlations for the two groups, there seems to be a slight tendency for a steer with a higher average daily gain to do better for all these characters than one with a lower average daily gain.

Efficiency had only one significant correlation with any of the three characters—dressing percentage for the 62 steers—and that was negative. It seems probable that this negative relationship was due to the animals with a high dressing percentage having more fat, and because of this they had utilized more feed in putting on weight than steers with more of their weight in muscle.

Correlation between slaughter grade and carcass grade were the highest found—0.69 and 0.71 for the 157 and 62 steers, respectively. This finding is in agreement with that of Black *et al.* (1938). Significant positive correlations were also obtained with dressing percentage for both the groups. Thus it can be concluded that this visual observation for slaughter grade is a fairly good indication of the animal's carcass qualities. Carcass grade and dressing percentage have a correlation of 0.45 and 0.55 for the 157 and 62 steers, respectively. Therefore it can be concluded that a carcass with a high dressing percentage tends to be superior in carcass grade.

In general, the agreement between the correlations for the two groups is quite close, only 5 of the differences out of 24 being significant. Since the total group (157 steers) has the advantage of the larger number of animals, while the subgroup (62 steers) has the advantage of more uniform treatment, one cannot say definitely which figure should be used where there is a difference. However, it seems reasonable to assume that the true value probably lies between the two values found.

Summary and Conclusions

This study was based on the data collected on 157 Milking Shorthorn steers bred and fattened at the Agricultural Research Center, Beltsville, Maryland. These steers were all fed individually in a record of performance test to a final weight of 900 pounds. Body measurements were taken just before slaughter. Slaughter grade, carcass grade and dressing percentage were taken under comparable conditions on all the animals. In addition to the total group, which varied somewhat in their treatment, a subgroup of the 157 steers consisting of 62 animals which received more uniform treatment was studied.

A considerable number of the correlations between the five body measurements dealt with in this paper and slaughter grade, carcass grade, and dressing percentage were high enough to be statistically significant and of some value for selection in a long-time breeding program.

Conclusions based on results from the group of 157 steers were: Steers of shorter height both at the withers and at the floor of chest, and steers that were shorter in length of body, tended to have slightly higher slaughter and carcass grades and a higher dressing percentage than more rangy steers.

Steers with a large circumference of fore-flank tended to make slightly higher slaughter grades.

Steers that were wide in the shoulder tended to make slightly higher slaughter and carcass grades than those that were narrower.

There seems to be a slight tendency for a steer with a higher average daily gain to do better on dressing percentage than one with a lower average daily gain.

Results from data on the group of 62 steers indicate: Steers with a large circumference of fore-flank tended to have a higher dressing percentage than those with a smaller circumference of fore-flank and steers with a high average daily gain tended to have a higher slaughter grade than those which did not gain so rapidly.

Results supported by data from both groups show that: Steers that had higher average daily gains tended to have higher carcass grades than those with lower average daily gains.

Slaughter grade was a fairly good indicator of carcass grade. It had a low but significant positive association with dressing percentage.

Carcass grade had a higher but intermediate positive association with dressing percentage.

Literature Cited

Black, W. H., B. Knapp Jr., and A. C. Cook, 1938. Correlation of body measurements of slaughter steers with rate and efficiency of gain and with certain carcass characteristics. Jour. Agri. Res. 56:465.

Fisher, R. A. 1946. Statistical methods for research workers. Oliver and Boyd, Edinburgh: 354 pp.

Hankins, O. G. and L. B. Burk. 1938. Relationship among production and grade factors of beef. Tech. Bul. U.S.D.A. 665. 40 pp., 23 figs.

Kohli, M. L., A. C. Cook and W. M. Dawson. 1951. Relations between some body measurements and certain performance characters in Milking Shorthorn steers. JOURNAL OF ANIMAL SCIENCE 10:352.

Lush, J. L. 1932. The relationship of body shape of feeder steers to rate of gain, to dressing percent, and to value of dressed carcass. Tex. Agr. Expt. Sta. Bul. 471, 30 pp.

Snedecor, George W. 1948. Statistical methods. Iowa State College, Ames, 485 pp.

Wallace, H. A. and G. W. Snedecor. 1931. Correlation and machine calculation. Iowa State College, Ames 30(4): 71 pp.

MOISTURE, ASH, AND FAT CONTENT OF CONNECTIVE TISSUE FROM CATTLE OF DIFFERENT AGES[1]

R. W. Bray, P. H. Phillips, and G. Bohstedt
University of Wisconsin[2]

QUALITY in fresh meat is measured by several physical characteristics such as age of the carcass or cut as indicated by the nature of the bone, color of fat and lean, firmness of fat and lean, and amount of marbling or internal finish. These are important in that they are indications of the qualities which affect palatability factors such as flavor, juiciness, and tenderness. Of these three factors, tenderness is the most important to the consumer.

Most investigators now agree that tenderness is influenced most by the amount and type of connective tissue in the muscle. Muscles containing large quantities of connective tissue are less tender than those containing smaller amounts. Likewise, the meat from young animals is more tender than that from older animals. A number of investigators have studied the chemical and molecular arrangement of connective tissue, yet very few studies have been made to explain, for example, why veal is more tender than the flesh from market beef.

Moulton (1940) has given the percentage composition of the ligamentum nuchae (predominantly elastin) to be 57.57% water, 0.47% ash, and 1.12% fat; likewise for the Achilles' tendon (primarily collagen) he reports 62.87% water, 0.47% ash, and 1.04% fat.

Since there is only limited information available regarding the characteristics of connective tissue from differently aged animals of the same species, certain basic data such as moisture, ash, and fat content seemed desirable.

Materials and Methods

It was decided to use the connective tissue from various parts of the carcass. Elastin samples were taken from the ligamentum nuchae. Collagen or white connective tissue was taken from a thick sheath of connective tissue that partially covers the biceps femoris muscle which is known as the bottom or outside round muscle. An additional sample of white connective tissue was taken from the chuck between the triceps and brachialis muscles.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.
[2] Departments of Animal Husbandry and Biochemistry, Madison, Wisconsin.

Samples of these tissues were taken from U.S. Good veal carcasses and U.S. Utility carcasses weighing from 100 to 110 pounds; from U.S. Good beef carcasses weighing about 550 pounds, and from U.S. Utility cow carcasses varying in weight from 400 to 700 pounds. The carcasses were held for different periods of time before taking the samples. The veal carcasses were held on the average 6 days before cutting, the U.S. Good beef 8 to 10 days, and the cow beef 2 to 6 days. The connective tissue samples were scraped free of all muscular tissue and wrapped in a good quality locker paper until time of analyses.

Moisture, ash, and fat determinations

Moisture was determined by first slicing and macerating the frozen tissue. Approximately a 5-gram sample of the macerated tissue was then placed in a previously dried-out, weighed, evaporating dish, and then dried for 18 to 20 hours at an oven temperature of 105 degrees centigrade. After being dried the sample was again weighed and the percentage moisture was calculated from the original moist weight.

After the samples were dried for moisture determination they were slowly charred over a gas flame. When thoroughly charred they were placed in a thermostatically controlled furnace at a temperature of 1200 degrees centigrade for 8 hours, or until ashing was complete. After ashing the samples were again weighed and percentage ash was calculated on a dry weight basis.

Fat determinations were made by first macerating the samples as in moisture determinations. The samples were then placed in an oven at 37 degrees centigrade to dry. About a 2-gram sample was then continuously extracted with diethyl ether in a Soxhlet-type extractor. Extraction was completed in 18 to 20 hours. After the ether was evaporated the fat was then weighed and calculated as the percentage of the dried weight of the sample.

The data for moisture and ash were treated statistically.

Results and Discussion

Connective tissue analyses

The average percentage for analyses of moisture, ash, and fat for the various samples of connective tissue are given in table 1. The analysis of these data is shown in table 2.

The moisture content of all samples of connective tissue studied exhibited the same trend. The difference in moisture content between samples of U.S. Good veal, beef, and Utility cow beef was highly

significant at the 1 percent level. That is, the moisture content of the veal connective tissue was significantly higher than that of U.S. Good beef and likewise the sample of connective tissue from the U.S. Good beef was significantly higher than that of the U.S. Utility cow beef.

The results seem to be in line with findings regarding muscle tissue. The moisture content of muscle decreases with the age of the animal.

TABLE 1. PERCENTAGE MOISTURE, ASH, AND FAT OF CONNECTIVE TISSUE

Elastin from ligamentum nuchae

Source of tissue	Moisture		Ash	
	No. samples	Percentage moisture	No. samples	Percentage ash
U.S. Good veal	26	60.47	25	1.32
U.S. Good beef	23	55.33	17	1.74
U.S. Utility cow	21	53.82	20	1.24

Connective tissue from chuck

Source of tissue	No. samples	Percentage moisture	Percentage ash	Percentage fat
U.S. Good veal	9	63.36	2.83	4.12
U.S. Good beef	24	58.96	1.59	5.02
U.S. Utility cow	16	56.07	1.21	5.92

Connective tissue from round

Source of tissue	No. samples	Percentage moisture	Percentage ash
U.S. Good veal	20	62.30	2.24
U.S. Good beef	22	57.26	1.92
U.S. Utility cow	17	57.09	1.17

Thus it would seem reasonable for the moisture content of connective tissue to follow a similar trend, since it is responsible for holding the muscle fibers in position.

The results obtained were slightly lower than those given by Moulton (1940) for the Achilles' tendon and the ligamentum nuchae. But they were in agreement in that the moisture content of the ligamentum nuchae was lower than that of the white connective tissue from either the chuck or round.

The ash content of the connective tissue studied followed a similar trend to that of moisture content. The veal samples were highest in

TABLE 2. ANALYSIS OF VARIANCE OF DATA IN TABLE 1

Source of variation	Ligamentum nuchae				Connective tissue (chuck)				Connective tissue (round)			
	Moisture		Ash		Moisture		Ash		Moisture		Ash	
	Degrees freedom	Mean square	Degrees freedom	Mean square	Degrees freedom	Mean square	Degrees freedom	Mean square	Degrees freedom	Mean square	Degrees freedom	Mean square
Between sources	2	289.94**	2	1.36	2	151.50**	2	7.87**	2	172.63**	2	10.48**
Within sources	67	5.47	59	0.46	46	10.61	46	0.18	56	5.95	56	0.06
Coefficient of variation		4.12		14.89		5.54		2.37		4.14		1.10

** $P \geqq 0.01$.

ash in all cases, except in the case of the elastin samples. No satisfactory explanation can be advanced for this observation. Yet the differences among the three sources (*i.e.*, U.S. Good veal, beef, and U.S. Utility cow beef) of connective tissue from the chuck and round were highly significant. Thus from these data it can be said that as the animal grows older, the lower will be the ash content of the white connective tissue.

From the data one can see that the ash content of the white connective tissue of the round and chuck were definitely higher than that of elastin from the same age animals. The elastin and collagenic type of connective tissue are quite different in other chemical characteristics and it seems probable that the ash content likewise could be different. Differences in function may possibly be a factor in making for the variation in chemical characteristics of the tissues.

The analysis of fat was only on the connective tissue from chucks of the differently aged animals. As one might expect, the fat content was somewhat higher in the cow beef and U.S. Good beef as compared to veal. This was expected, since fat is deposited throughout the body much more readily after an animal reaches maturity.

Men in the industry generally believe that meat of an animal becomes more tender with finish or fattening. Since the U.S. Utility cow beef connective tissue contained more fat than that of the other samples, it would seem that other factors than fat within the connective tissue are responsible for tenderness.

Summary

Elastin and collagenic connective tissues from differently aged cattle were analyzed for moisture, ash, and fat content. The data were treated statistically and it was found that the moisture and ash content of connective tissue decreases in cattle as the animal becomes older. On the other hand, the fat content of connective tissue was found to increase with age of the animals. The moisture and ash content of the collagenic connective tissue is significantly higher than that of the elastin connective tissue.

Literature Cited

Moulton, C. R. and W. L. Lewis. 1940. Meat through the microscope. Institute of Meat Packing, University of Chicago, p. 36.

A STUDY OF MEAT CHARACTERISTICS OF KARAKUL SHEEP

O. G. HANKINS, R. L. HINER AND V. L. SIMMONS [1]
U. S. Department of Agriculture[2]

KARAKUL sheep are primarily a fur-producing breed but under conditions of practical production they also produce meat and wool of commercial value. No attempts have been made to develop a mutton strain; consequently, these sheep lack some of the desirable characteristics found in the mutton breeds. However, in the maintenance of breeding flocks of Karakul sheep for lambskin fur production, the culling of mature ewes that fail to meet fur producing standards is necessary. Because of the general lack of knowledge concerning the meat producing qualities of these sheep, breeders encounter much prejudice in marketing their animals, which they feel is often unjustified. They are therefore much interested in determining the value of, and acquainting the public with, the merits of these sheep when used for meat purposes. Discrimination against the Karakul as a slaughter animal is reflected in lower prices received for them on the livestock market than for sheep of the mutton and wool breeds. If the Karakul breeder could have greater opportunity to dispose of inferior fur producing animals for meat purposes profitably, the added returns would enable him to maintain his flocks to better advantage.

Little, if any, research has been conducted on the meat producing qualities of Karakul sheep. The object of this paper, therefore, is to present results relating to the slaughter, carcass and meat characteristics of Karakul ewes handled under farm flock conditions.

Material and Methods

Fifty-seven ewes of Karakul breeding were available for this study from the flock which the Bureau of Animal Industry maintained for experimental purposes at the Agricultural Research Center, Beltsville, Maryland, from 1928 to 1949. Of these ewes, 12 were purebred Karakul and the remainder were grades (75.0 to 99.8 percent Karakul) consisting of 22 Karakul X Blackfaced Highland, 15 Karakul X Corrie-

[1] The authors give credit to Edith C. Weir and Harry Slofsky of the Bureau staff for conducting organoleptic tests and for statistical work, respectively, in connection with the study.
[2] Bureau of Animal Industry, Agricultural Research Administration.

dale, and 8 Karakul X Navajo. They ranged in age from 10 months to 10 years 11 months, with an average of 4.8 years. The variation in liveweight (unshorn) was from 66 to 163 pounds with a mean of 101.5 pounds. Figure 1 shows a ewe that was representative of those included in the study. Figure 2 shows the same animal shorn.

The flock was handled in a manner comparable with the established farm practices used in the management of sheep. Use was made of

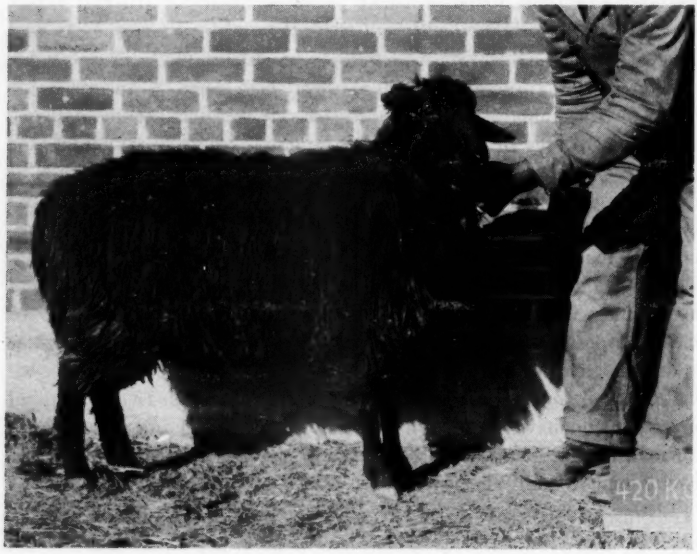


Figure 1. A representative of the ewes included in the study.

temporary and permanent pasture crops in the summer and barn feeding was practiced during the winter. By these practices the ewes were kept in the thrifty condition of a well managed breeding flock. No special feeding for fattening purposes was used. All the ewes were slaughtered during the period December 1949 to March 1950.

Procedure

The live weight of each ewe was determined immediately prior to slaughter. After slaughter the forefeet were taken off and the pelt was

removed in the customary manner. The head was separated from the neck at the atlas joint and the abdominal and thoracic viscera were removed, leaving the kidney and kidney fat intact. The carcasses were retained in one piece, that is, they were not separated into two sides by splitting down the backbone. Weights of the warm dressed carcasses were taken about 30 minutes after slaughter and the chilling

Figure 2. The same ewe as shown in figure 1 after removal of the fleece.

was done at approximately 35° F. for 48 to 72 hours, after which weights of chilled carcasses were determined.

Prior to slaughter the individual ewes were graded by a committee of three under the system which recognizes the six grades of Prime, Choice, Good, Medium, Common and Cull and three subdivisions of each. The carcasses were likewise graded after chilling.

Measurements of the carcasses were taken to determine the length of body from the anterior point of the shoulder to the hip bone, and length of leg from the hip bone to the first joint of the foot. Width of

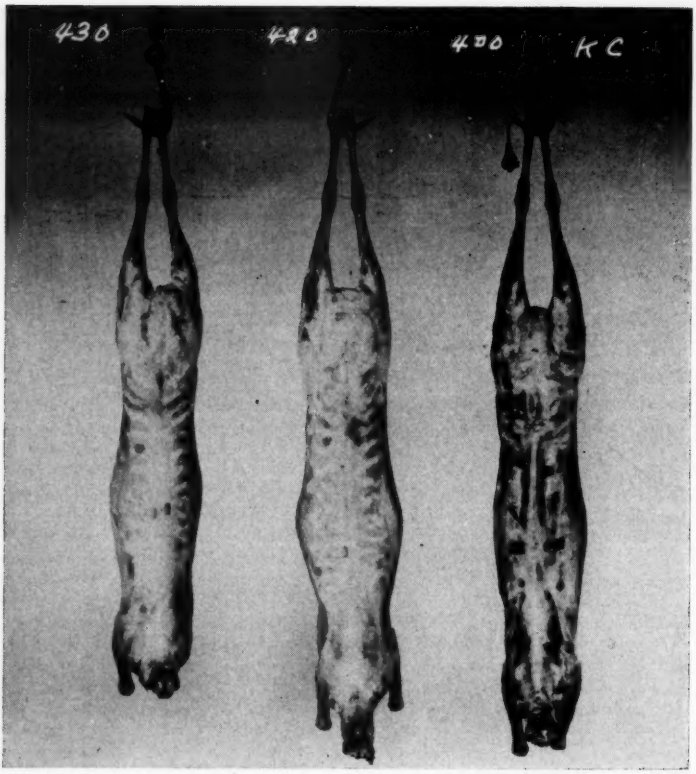


Figure 3. Dressed carcasses of three animals included in the study. From left to right the separable fat content of the rib cuts was 22.01, 33.70 and 7.92 percent. The middle carcass represents the same individual as shown in figures 1 and 2.

carcass was measured at the first rib, hip bone, and widest point of the hind legs whereas total depth of body was determined at the seventh rib. The circumference of the hind leg at one-third of the distance from the base of the aitch bone to the distal end of the tibia-fibula bone was determined and divided by the distance between the two points mentioned to give a factor representing plumpness of the leg.

In cutting the carcasses the method described in U.S.D.A. Technical

Bulletin No. 944, "Estimation of the composition of lamb carcasses and cuts," was in general followed closely. This included trimming the leg cuts to remove any surplus fat.

Since it has been determined in work on other sheep, and reported in the publication just mentioned, that the composition of the rib cut is an excellent index of the composition of the entire dressed carcass, the nine-rib cuts from both sides of each carcass were analyzed for separable fat, lean meat, and bone and ligament content. These separations were made with great care and the several components were weighed to an accuracy of 0.01 pound.

The right hind leg from each of a representative group of the ewes was roasted by a standard method and the cooked meat was judged with respect to factors of palatability by a panel of experienced judges. Tenderness was also measured by an objective method which determines the resistance of a sample of the cooked meat to shearing action.

Results

The 57 ewes varied widely in important carcass and meat characteristics. Dressing percentage, for example, ranged from 30.6 to 55.4 with a mean value of 44.8. Other examples were carcass grade with a low of "low Cull" and a high of "high Good"; yield of rib cut, 5.00 and 10.68 percent; fatness (according to the rib sample), 2.05 and 44.26 percent, and tenderness, "very tough" and "tender." The corresponding means were "Medium" with respect to grade, 7.6 percent in yield of rib cut, 28.8 percent in fat content of rib cut, and "slightly tough" in degree of tenderness.

Preliminary study of the data indicated that important meat characteristics were not closely related to the age of the animals. Fatness appeared to be a much more significant controlling factor and it was therefore decided to analyze the data on that basis. Consequently the 57 ewes were subdivided into six classes according to fat content of the rib cuts, as follows: (1) below 6.00 percent, (2) 6.00 to 14.24 percent, (3) 14.25 to 22.49 percent, (4) 22.50 to 30.74 percent, (5) 30.75 to 38.99 percent, and (6) 39.00 and above. It will be noted that groups 2, 3, 4 and 5 represent intervals of 8.25 percent. Figures 3 and 4 show back and side views of the dressed carcasses of three of the ewes. From left to right the percentage of separable fat in their rib cuts was 22.01, 33.70 and 7.92. Thus the three carcasses represent classes 3, 5 and 2 of the six classes mentioned above.

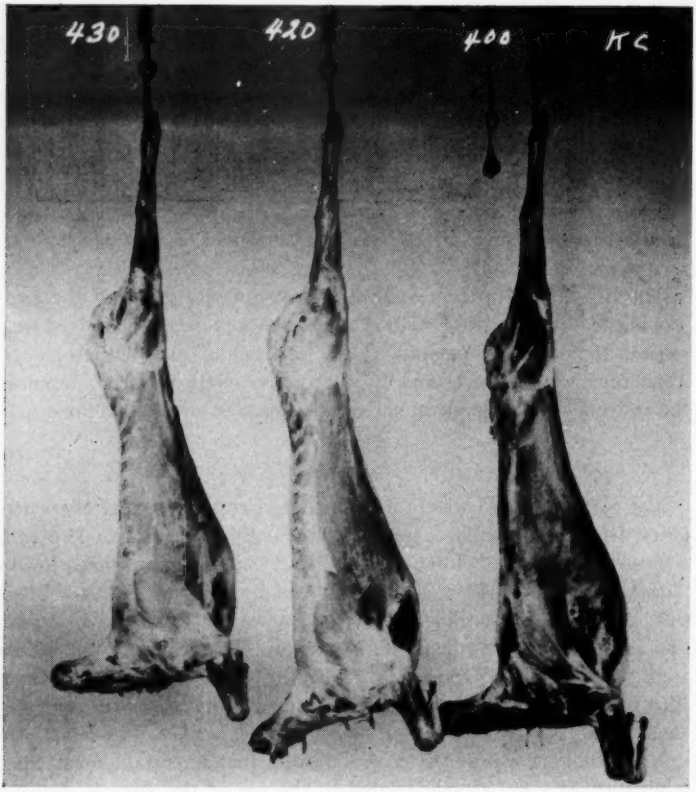


Figure 4. Side views of the same carcasses as shown in figure 3.

Attention is directed to table 1 in which are shown the mean values for separable fat content of the rib cut of the six classes of Karakul ewes. The minimum difference in the mean percentage of fat content between any two successive classes is between 6 and 7 percent and the maximum difference is between 11 and 12 percent. The table shows further that with subdivision of the ewes on the basis indicated the mean liveweights ranged from 71.0 pounds for the least fat to 139.3 pounds for the fattest.

As expected, dressing percentage varied directly with fatness and liveweight at slaughter but the extent of the variation in that char-

TABLE 1. MEAN FATNESS, LIVE WEIGHTS, DRESSED WEIGHTS, DRESSING PERCENTAGES AND CARCASS GRADES OF KARAKUL EWES CLASSIFIED ACCORDING TO FATNESS

Class Interval (Separable fat content of rib cut)	Number of animals	Separable content of rib cut	Live weight at slaughter (unshorn)	Weight of dressed carcass		Dressing percentage		Carcass grade
				Warm	Chilled	Warm carcass	Chilled carcass	
percent		percent	pounds	pounds	pounds			
Below 6.00	1	2.1	71.0	23.0	21.8	32.3	30.6	Low Cull
6.00–14.24	12	8.7	88.6	35.4	33.7	40.1	38.1	Cull
14.25–22.49	10	19.9	92.8	40.9	39.3	45.0	43.4	Low Medium
22.50–30.74	12	27.1	94.8	44.3	43.0	46.9	45.5	High Medium
30.75–38.99	15	35.2	107.5	51.7	50.6	48.3	47.2	Low Good
39.00 and above	7	42.4	139.3	72.5	71.3	52.0	51.1	High Good
General mean	57	28.8	101.5	46.9	45.5	46.2	44.8	Medium

acteristic is worthy of special attention. The chilled carcass of the thinnest ewe had a dressing percentage of only 30.6 and the next thinnest class, 38.1 percent. However, the fattest class, consisting of seven ewes, "dressed" more than 50 percent.

Table 1 also shows that with increase in fatness there was a definite, corresponding increase in grade of carcass. This latter increase progressed to the point where as a group the fattest ewes, having a mean separable fat content of rib cut of 42.4 percent, were found to be high Good as dressed carcasses.

TABLE 2. MEAN VALUES FOR CERTAIN MEASURABLE CARCASS CHARACTERISTICS OF KARAKUL EWES CLASSIFIED ACCORDING TO FATNESS

Class Interval (Separable fat content of rib cut)	Number of animals	Length of body	Length of hind leg	Mean width of body	Ratio of total length of body and leg to mean width	Depth of body	Plumpness of leg
percent		mm.	mm.	mm.		mm.	index
Below 6.00	1	562.0	670.0	140.3	8.78:1	290.0	78.0
6.00–14.24	12	580.3	663.5	167.0	7.45:1	278.6	82.8
14.25–22.49	10	582.1	665.0	175.5	7.11:1	289.5	89.4
22.50–30.74	12	563.2	657.2	179.5	6.80:1	278.0	90.5
30.75–38.99	15	584.0	672.8	185.6	6.77:1	288.7	93.9
39.00 and above	7	612.4	688.0	211.4	6.15:1	307.0	104.1
General mean	57	581.6	668.0	181.0	6.90:1	286.7	91.0

Characterization of the Karakul ewe carcasses in terms of linear measurements brings out several interesting facts. As shown by table 2, no consistent increase in length of body accompanied the increase of fatness, although the thinnest ewe was the shortest and the group of seven fattest ewes were the longest. The same picture in general was presented by the length of hind leg and depth of body. On the other hand, the mean width of body and plumpness of leg varied directly with fatness of the carcasses. In fact the correlation between plumpness of leg and fatness was found to be 0.76. Moreover, the ratio of total length of body and hind leg to mean width definitely became narrower as the fat content increased. That is, for example, the width of the thinnest carcass was only 11.4 percent as great as the total length whereas the corresponding value for the fattest carcasses was 16.3 percent.

The yield of the various primary cuts is one of the most important factors considered in this carcass evaluation of Karakul ewes. Table 3 shows that when the carcasses were separated into the several cuts the

yield of leg increased rapidly with increasing fatness, up to 12.39 percent, after which the changes were of small magnitude. Similar results were obtained with the shoulder and breast cuts. On the other hand, the yields of loin and rib cuts continued to increase at a relatively rapid rate throughout the range of fatness. In fact the yield of each of these two cuts by the fattest group of animals was approximately double that of the thinnest ewe. Summation of the percentages of the most popular cuts—leg, loin and rib—for each group of ewes shows that there was an uninterrupted increase in this combined yield from the least fat to the fattest group. The minimum in this respect was 18.06 and the maximum 26.76 percent.

TABLE 3. MEAN YIELDS OF CUTS FROM KARAKUL EWES CLASSIFIED ACCORDING TO FATNESS

Class Interval (Separable fat content of rib cut)	Number of animals	Cuts							Loss-in trimming legs
		Legs (trimmed)	Loin	Rib	Shoulders	Breast	Neck	Kidney fat	
percent		percent	percent	percent	percent	percent	percent	percent	percent
Below 6.00	1	9.30	1.97	4.79	6.06	4.23	1.97	0.28	15.4
6.00–14.24	12	11.44	2.85	6.08	7.38	5.48	1.73	0.53	16.1
14.25–22.49	10	12.39	3.19	6.90	8.21	6.06	1.77	0.80	17.8
22.50–30.74	12	12.76	3.56	7.53	8.34	6.03	1.75	1.44	21.9
30.75–38.99	15	12.58	3.91	8.01	8.42	6.20	1.69	1.96	24.3
39.00 and above	7	12.75	4.41	9.60	8.54	6.48	1.66	2.59	27.4
General mean	57	12.36	3.59	7.61	8.17	6.03	1.72	1.49	22.0

It is brought out further in table 3 that in general a decrease in the percentage of neck, as well as a marked increase in kidney fat content, accompanied the change in fatness of rib cut from 2.1 to 42.4 percent. Furthermore, with increase in fatness of the ewes there was a rather striking increase in trimming loss from the legs, this loss attaining the large maximum of 27.4 percent. The tendency for Karakul sheep to deposit a large quantity of fat in the tail and around the tail head and the necessity of trimming much of this away were believed to be the major factors involved in the rapid increase in trimming loss.

Meat consumers, as a rule, are greatly concerned with the proportions of fat, lean and bone. Therefore, the physical composition of the carcasses was one of the basic factors receiving attention in this study. As previously stated, the nine-rib cuts were used as the carcass sample. According to analysis of this sample from the 57 carcasses, the mean separable fat content was 28.8 percent. This was shown in table 1 and

is brought out again in table 4 together with the mean values for other components including lean meat, total edible meat and bone—47.3, 76.1 and 23.9 percent, respectively. In this latter table attention is called to the fact that with increase in fatness there was some decrease in lean meat content as well as a striking increase in percentage of total edible meat and an equally striking decrease in percentage of bone. These changes in the proportions of the other components were of course largely, if not entirely, controlled by the change in fat content.

TABLE 4. MEAN PHYSICAL COMPOSITION OF RIB SAMPLES FROM KARAKUL EWES CLASSIFIED ACCORDING TO FATNESS

Class Interval (Separable fat content of rib cut)	Number of animals	Component			
		Separable fat	Lean	Total edible meat	Bone
percent		percent	percent	percent	percent
Below 6.00	1	2.1	47.8	49.9	50.1
6.00–14.24	12	8.7	58.1	66.8	33.2
14.25–22.49	10	19.9	51.8	71.7	28.3
22.50–30.74	12	27.1	49.2	76.3	23.7
30.75–38.99	15	35.2	43.9	79.1	20.9
39.00 and above	7	42.4	39.9	82.3	17.7
General mean	57	28.8	47.3	76.1	23.9

Calculation shows that on the average the edible meat-bone ratio was 3.2:1. The variation in this respect among the six classes of ewes was from about 1:1 to 4.7:1.

Roasted legs from 32 of the ewes representing the second to sixth classes were subjected to tests for palatability. Judging was done with the aid of a grading chart, which included seven grades, evaluated 7, 6, 5, 4, 3, 2 and 1. Thus, 7 was the highest score possible and 1 the lowest. Table 5 shows little variation among the five classes with respect to desirability of aroma. All averaged "moderately desirable." However, in desirability of both flavor of fat and flavor of lean the judging panel rated the roasts from the thinnest class of ewes definitely lower than those from the other four classes which, as in the case of aroma, averaged "moderately desirable."

The scores for quantity of juice for the various classes did not deviate greatly from the general mean score of 4.50. That score indicates that on the average the meat was on the borderline between "slightly

dry" and "moderately juicy." The same situation existed with respect to the quality or richness of the juice.

Table 5 further indicates that fatness had considerable influence on tenderness. Although, for some undetermined reason, the first class represented in the table was relatively high with respect to tenderness and therefore out of line, the other four classes, each represented by at last five ewes, showed an improvement in tenderness as the mean fat content increased from 19.9 to 42.4 percent. The first of these four classes was graded as "tough" on the average and the last as "moderately tender."

TABLE 5. MEAN VALUES FOR PALATABILITY OF ROASTED LEGS OF KARAKUL EWES CLASSIFIED ACCORDING TO FATNESS

Class Interval (Separable fat content of rib cut)	Number of animals	Desirability of			Juiciness		Tenderness	Resistance to shearing
		Aroma	Flavor of fat	Flavor of lean	Quantity	Quality		
percent								pounds
Below 6.00	0	—	—	—	—	—	—	—
6.00–14.24	2	5.00	4.50	4.60	4.80	4.40	4.20	19.0
14.25–22.49	5	5.27	5.25	5.27	4.41	4.35	3.31	30.4
22.50–30.74	9	5.30	5.23	5.41	4.58	4.66	4.17	22.2
30.75–38.99	10	5.25	5.35	5.32	4.26	4.44	4.30	19.5
39.00 and above	6	5.23	5.27	5.33	4.77	4.50	4.73	17.8
General mean	32	5.24	5.22	5.29	4.50	4.50	4.18	21.6

Summary

In maintaining flocks of Karakul sheep for lambskin fur production, culling ewes that fail to meet fur producing standards is necessary. Breeders are interested in determining the value of, and acquainting the public with, the merits of these sheep when used for meat purposes. At present much prejudice is encountered in the marketing of sheep and lambs of this breed.

Fifty-seven purebred and high grade Karakul ewes from the Beltsville flock of the U. S. Bureau of Animal Industry were used in this study. They ranged from 10 months to 10 years 11 months in age, 66 to 163 pounds in weight (unshorn) and varied widely in fatness.

The ewes were subdivided into six classes according to fat content of the rib cuts (an excellent carcass sample). With the mean fat content of these classes ranging from 2.1 to 42.4 percent, live weight (for example) varied from 71.0 to 139.3 pounds, dressing percentage from

30.6 to 51.1, carcass grade from low Cull to high Good, index of plumpness of leg from 78.0 to 104.1, and yield of preferred cuts from 16.06 to 26.76 percent. Corresponding mean values were liveweight 101.5 pounds, dressing percentage 44.8, carcass grade Medium, index of plumpness 91.0, and yield of preferred cuts 23.56 percent.

Other examples of variations that accompanied increased fatness were total edible meat from 49.9 to 82.3 percent and tenderness from "tough" to "moderately tender" (for last four classes). Means were 76.1 percent and "slightly tough," respectively.

EFFECTS OF CORPORA LUTEA REMOVAL AND REPLACEMENT WITH PROGESTERONE ON PREGNANCY IN GOATS[1, 2]

J. MEITES, H. D. WEBSTER, F. W. YOUNG,[3] F. THORP, JR., AND R. N. HATCH[4]

Michigan Agricultural Experiment Station

PROGESTERONE is predominantly a hormone of pregnancy and is required for (a) the growth and secretion of the glands in the uterine mucosa preparatory to implantation of the ovum (b) the nutrition and protection of the embryo during the time when it is lying free in the uterus (c) the development of the placenta and membranes after implantation (d) lobule-alveolar mammary growth (e) maintenance of a quiescent uterus and (f) inhibition of ovulation and estrus.

The corpora lutea are essential throughout all or most of pregnancy and apparently constitute the principal source of progesterone in the goat (Drummond-Robinson and Asdell, 1926), cow (Hammond, 1927; Sartoris, 1938), rabbit (Corner, 1928), and rat (Johnson and Challans, 1930).

In the guinea pig (Loeb, 1923), mare (Hart and Cole, 1934), monkey (Hartman, 1941) and man (Asdell, 1928) the corpora lutea are not essential after mid-pregnancy since at that time the ovaries can be removed without interfering with the continuance of pregnancy. These species presumably posses extra-ovarian sources of progesterone. In sheep, Casida and Warwick (1945) reported that removal of the corpora lutea or ovariectomy before or after mid-pregnancy resulted in the continuance of pregnancy in four out of ten animals.

It was the purpose of the present investigation (1) to attempt to verify the need for the corpora lutea of pregnancy in goats, (2) to see whether pregnancy could be maintained after removal of only some of the corpora lutea present, and (3) to determine the minimal daily dose of progesterone which would maintain gestation after excision of all the corpora lutea.

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1197.

[2] Part of these data were published as an abstract in the JOURNAL OF ANIMAL SCIENCE 7:542 (1948).

[3] Deceased.

[4] Departments of Physiology and Pharmacology, Pathology, and Surgery and Medicine.

Experimental Procedure and Results

Twenty-one goats of mixed or pure Toggenburg and Saanen strains were bred during the fall months of 1947–1949. Laparotomies were performed on all the goats on the 100th or 125th day of gestation under paravertebral anesthesia (novocaine). The corpora lutea were carefully shelled out with a scalpel, leaving a smooth cavity in the ovaries. In two goats the entire ovaries were removed. In all cases the uterus and fetuses were distributed as little as possible during the operation.

Eight goats served as controls and received no further treatment following the operation. The other 13 goats were each injected sub-

TABLE 1. EFFECTS OF REMOVAL OF CORPORA LUTEA OR OVARIECTOMY UPON PREGNANCY IN GOATS

Goat No.	Days pregnant when operated	Type of operation	No. of fetuses found	Results
201	100	2 corpora lutea removed	2	Aborted 2 fetuses on 102nd day
902A	100	" " " "	2	" " " " " "
265	100	" " " "	2	" " " " " "
902B	125	" " " "	2	" " " " 127th "
268	125	Both ovaries removed	2	" " " " " "
243	100	1 corpus luteum removed	2	Aborted 2 fetuses on 130th day; 1 fetus decomposed and other normal.
205	135	1 corpus luteum removed	2	2 kids born on 151st day.
901	100	" " " "	2	Gestation continued.
	117	2nd " " "	2	Aborted 2 fetuses on 117th day.

cutaneously with crystalline progesterone[5] in oil, starting on the day of operation and continuing until they aborted or until the end of the normal gestation period.

The effects of removing the corpora lutea or both ovaries are shown in table 1. Excision of all the corpora lutea in four goats (201, 902A, 265, 902B) and of both ovaries in one goat (268) resulted in prompt abortion two days later. In three other goats (243, 205, 901), the removal of only one of two corpora lutea permitted the continuance of gestation for variable periods of time. Goat 243 aborted two fetuses 30 days following the removal of one of two corpora lutea on the 100th day of gestation, but one fetus was decomposed and may have died shortly after the operation. In goats 205 and 901 the removal of one of two corpora lutea resulted in continuance of normal pregnancy. Seventeen days after removing the first corpus luteum in goat 901, the

[5] The authors are indebted to Dr. H. O. von Rosenberg of Parke-Davis and Co., Detroit, Michigan, for most of the progesterone used in these studies.

second corpus luteum was removed and she aborted two fetuses two days later.

Table 2 shows the effects of injecting different doses of progesterone on the maintenance of pregnancy after removal of all the corpora lutea. In three goats (203, 204, 904) operated on the 100th day of pregnancy,

TABLE 2. EFFECTS OF PROGESTERONE AFTER REMOVAL OF CORPORA LUTEA OR OVARIECTOMY UPON PREGNANCY IN GOATS

Goat No.	Days pregnant when operated	Type of operation	No. of fetuses found	Amt. of progesterone given		Results
				daily mg.	total days	
203	100	2 corpora lutea removed	2	25	49	2 kids born on 151st day
204	"	" " " "	2	25	49	" " " "
904	"	" " " "	2	25	49	" " " "
236	"	" " " "	?	15	48	1 kid born on 151st day
235	"	" " " "	2	15	48	2 kids born on 151st day
237	"	" " " "	2	15	48	" " " "
86A	"	" " " "	2	15	8	Aborted 2 fetuses on 110th day
239	"	1 corpus luteum "	1	10	48	1 kid born on 150th day
86B	"	3 corpora lutea "	3	10	13	Aborted 3 fetuses on 115th day
267	"	Both ovaries "	2	10	4	Aborted 2 fetuses on 104th day
263	125	1 corpus luteum "	1	10	23	1 kid born on 150th day
273	"	2 corpora lutea "	2	10	23	Died of empyema on 148th day; fetuses appeared normal
271	"	" " " "	2	10	2	Aborted 2 kids on 127th day

25 mg. of progesterone daily maintained normal gestation to term. Fifteen mg. of progesterone daily was also sufficient to maintain pregnancy in four goats (236, 235, 237, 86A). Injections of progesterone in goat 86A were inadvertantly missed after the eighth day following removal of the corpora lutea, and this goat promptly aborted two days later. Ten mg. of progesterone daily enabled four goats (239, 86B, 263, 273) to continue in gestation for variable periods of time following removal of the corpora lutea. Injections in goat 86B were stopped thirteen days after removal of three corpora lutea in order to confirm

that ten mg. of progesterone was sufficient to maintain gestation, and this animal promptly aborted two days later. Ten mg. of progesterone did not maintain pregnancy after removal of both ovaries in goat 267.

Discussion

These results confirm the original observations of Drummond-Robinson and Asdell (1926) in eight goats that the corpora lutea are essential for the maintenance of gestation after mid-pregnancy. With possibly one exception (goat 236), the corpora lutea found in the ovaries corresponded to the number of fetuses present in the goats. The corpora lutea apparently secrete more progesterone than necessary for the maintenance of pregnancy, as indicated by the observation that removal of one of two corpora lutea enabled three goats to continue in gestation for variable periods of time. Corner (1937) similarly observed that the total number of corpora lutea in pregnant rabbits secrete more progesterone than necessary to maintain gestation.

These studies indicate that the minimal amounts of progesterone required to maintain gestation in goats during the last 50 days of pregnancy is of the order of ten mg. daily. It is interesting that Dutt and Casida (1948) also found in sheep that the injection of five or ten mg. of progesterone daily was sufficient to suppress normal estrus and ovulation in most cases. Inasmuch as these constitutes specific functions of progesterone during pregnancy, it is possible that five to ten mg. represent the daily requirements of sheep during gestation.

It is possible that smaller amounts of progesterone than ten mg. daily would maintain gestation during the first 100 days in goats, since the normal titers of ovarian hormones in the blood and urine of other species has been shown to increase generally throughout most of pregnancy. It must also be mentioned that the actual total daily requirements of goats or sheep for progesterone during pregnancy may be less than indicated by studies based on subcutaneous injections of the hormone, since smaller daily quantities of progesterone may suffice if they are secreted more or less continuously by the ovaries throughout the day.

It is interesting that pregnant women, whose average body weights fall within the same range as pregnant goats, have been shown to secrete the equivalent of 60 to 100 mg. of progesterone daily during the last third of pregnancy (Corner, 1941). On the basis of the present study, it would appear that goats secrete considerably less than this quantity during pregnancy. Recent observations by Raeside and Turner (1950a, 1950b) indicate that the pregnant cow, which may weigh eight

to twelve times as much as goats or women, requires on the order of 50 to 75 mg. of progesterone daily by injection to maintain gestation after removal of the corpus luteum. When added to the recent report of Asdell (1947) that only very small doses of estrogen are required to induce estrus in cows, it is possible to conclude that the goat, sheep and cow are unique among mammalian species in their low requirements for ovarian hormones.

Summary

1. Laparotomies were performed on 21 goats either on the 100th or 125th day of gestation. All or some of the corpora lutea were removed from 19 goats and the entire ovaries were removed from two goats. Eight goats received no further treatment while 13 goats were injected daily with 25, 15 or 10 mg. of progesterone.
2. Excision of all the corpora lutea in four goats and of both ovaries in one goat resulted in prompt abortion two days later, confirming the need for the corpora lutea during the last third of pregnancy in goats.
3. In 20 of the 21 goats the number of corpora lutea found in the ovaries corresponded to the number of fetuses. Excision of only one of two corpora permitted three goats with two fetuses each to continue in pregnancy for variable periods of time, indicating that more progesterone is normally secreted by the corpora lutea than necessary to maintain gestation.
4. When all the corpora lutea were removed, subcutaneous injections of 25 mg. of progesterone daily maintained pregnancy in three of three goats, 15 mg. in four of four goats and 10 mg. in four of six goats. It is concluded that the progesterone requirements of goats is of the order of 10 mg. daily during the last third of pregnancy.

Literature Cited

Asdell, S. A. 1928. The growth and function of the corpus luteum. Physiol. Rev. 8:313.

Asdell. S. A. 1947. Chap. 39 in Dukes: The physiology of domestic animals, 6th edition, Comstock Publishing Co., Ithaca, N. Y., pp. 762–763.

Casida, L. E. and E. J. Warwick. 1945. The necessity of the corpus luteum for maintenance of pregnancy in the ewe. JOURNAL OF ANIMAL SCIENCE 4:34.

Corner, G. W. 1928. Physiology of the corpus luteum. I. The effect of very early ablation of the corpus luteum upon embryos and uterus. Amer. Jour. Physiol. 86:74.

Corner, G. W. 1937. The rate of secretion of progestin by the corpus luteum. Cold Spring Harbor symposia on quantitative biology 5:62.

Corner, G. W. 1941. Corpus Luteum Hormone, Jour. Amer. Med. Assn. 116:591.

Drummond-Robinson, G. and S. A. Asdell. 1926. The relation between the corpus luteum and the mammary gland. Jour. Physiol. 61:608.

Dutt, R. H. and L. E. Casida. 1948. Alteration of the estrual cycle in sheep by use of progesterone and its effect upon subsequent ovulation and fertility. Endocrin. 43:208.

Hammond, John. 1927. The physiology of reproduction in the cow. Cambridge Univ. Press, London.

Hart, G. H. and H. H. Cole. 1934. The source of estrin in the pregnant mare. Amer. Jour. Physiol. 109:320.

Hartman, C. G. 1941. Non-effect of ovariectomy on the twenty-fifth day of pregnancy in the rhesus monkey. Proc. Soc. Exp. Biol. and Med. 48:221.

Johnson, G. E. and J. S. Challans. 1930. Ovariectomy and corpus luteum extract experiments in pregnant rats. Anat. Rec. 47:300 (Abs.).

Loeb, Leo. 1923. Mechanism of sexual cycle with special reference to corpus luteum. Amer. Jour. Anat. 32:305.

Raeside, J. I. and C. W. Turner. 1950a. A preliminary report on the role of progesterone in the maintenance of pregnancy in the cow. Jour. of Dairy Sci. 33:382 (Abs.).

Raeside, J. I. and C. W. Turner. 1950b. Progesterone in the maintenance of preynancy in dairy heifers. JOURNAL OF ANIMAL SCIENCE 9:681 (Abs.).

Sartoris, P. 1938. Sui rapporti fra il corpo luteo e gravidanza nella bovina. [The relation between corpus luteum and pregnancy in the cow.] Nuovo Ercol. 43. 133. Cited from Animal Breed. Abs. 1940, 8:370

A PERMANENT RUMEN FISTULA CANNULA FOR COWS AND SHEEP[1]

G. E. Stoddard,[2] N. N. Allen, W. H. Hale,[3] A. L. Pope, D. K. Sorensen, and W. R. Winchester[4]

University of Wisconsin[5]

RUMEN fistulae have been used extensively for studying digestion in ruminants. A permanent fistula affords ready access to the rumen for sampling its contents and for studying its physiology without sacrificing the animal.

Flourens as early as 1833 reported work in which rumen and stomach fistulae were used on sheep. Later, Colin (1886) used the same technique in studies with oxen. No attempt was made to close the fistular opening by mechanical means. Various other German and French investigators employed rumen fistulae in their studies. These have been discussed by Wester (1926), Schalk and Amadon (1928), and Quin *et al.* (1938), who have used fistulated animals for more recent experiments. Rumen fistulae have also been used for work with calves as indicated by Wester (1926) and Anderson and Wise (1944).

Schalk and Amadon (1928) closed the fistula with a block of wood kept in position by a flap of leather on the inside and a flat piece of wood on the outside, all held together with a wire. Diernhofer (1928) employed a similar method with a cork block and rubber flaps, held together with twine soaked in olive oil and iodine. Closures designed to prevent loss of gases have included an inflated football bladder (Phillipson and Innes, 1939) and a special vulcanized rubber inflation cannula equipped with sampling valves (Cole *et al.*, 1942).

In experiments with sheep, Quin *et al.* (1938) tried several methods of closure with varied success. Tubes of aluminum or chromium plated brass were unsatisfactory because of corrosion and electrolysis. An ebonite tube with a base flange to help hold it in place was found to be more satisfactory.

Phillipson and Innes (1939) improved the ebonite cannula by fitting it with an outer clamp. Several of these cannulae were used in sheep and one in a cow.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.
[2] Present address: Department of Animal Husbandry, Iowa State College, Ames, Iowa.
[3] Present address: Animal Science Department, Univ. of Illinois, Urbana, Ill.
[4] Present address: Valley Veterinary Hospital, Rosemead, California.
[5] Departments of Dairy Husbandry, Animal Husbandry, and Veterinary Science.

The cannula described herein, similar to the one of Phillipson and Innes (1939), was designed to facilitate sampling and to minimize loss of fluids and gases without interfering seriously with rumen activity.

Cannula Design and Operative Procedure for Cows

A goat was used to develop operative technique and to test the design and operation of the cannula. The cannula was made of lucite, a transparent plastic, and inserted by an operative procedure similar to that of Schalk and Amadon (1928). Experience with this cannula led to improvements in the design of those subsequently used in cattle and sheep.

The design of the cannula for cows is shown in figure 1. In order to limit the size of the fistula, the base flange is threaded to the tube. It is constructed in a flattened elliptic shape so that when detached it will pass readily through the opening into the rumen. When in position it anchors the tube securely and fits the curvature of the rumen. The dimensions of the parts of the cannula used for cows are: length of tube, 24 cm.; inside diameter of tube, 5 cm.; length of threads on outer end of tube, 18 cm.; length of threads on base end of tube, 1 cm.; diameter of outside collar, 14.7 cm.; length and width of base flange, 19 by 9.4 cm.; outside diameter of the knurled adjusting ring and cap, 9.2 cm.; and thickness of material (all pieces), 0.9 cm.

Water and feed should be withheld for 24 hours. prior to the operation to reduce the moisture as well as the bulk of the rumen contents.

The operative area is located in the left paralumbar fossa, a triangular depression in the flank between the last rib and external angle of the ilium. This area is thoroughly scrubbed, shaved, and painted with tincture of iodine. Epidural and local anesthesia are employed, and the animal is kept in a standing position. Approximately 15 ml. of a 2 percent solution of procaine hydrochloride are injected epidurally, and the local anesthesia is produced with 1 percent solution of procaine hydrochloride injected into the skin and subcutaneous tissues.

The incision in the skin starts just below the transverse processes of the lumbar vertebrae and extends obliquely downward and forward for about 5 inches. The underlying subcutaneous tissue, the obliquus abdominis externus, obliquus abdominis internus, and peritoneum are incised, exposing the rumen. An umbilical tape about 1 ft. long is inserted through a fold of the rumen wall near the upper end of the incision, and the ends of the tape are tied together. Three others are inserted in a similar manner, one about 2 ins. anterior to the first, the

other two at the ventral commissure of the skin incision. Traction on these brings the wall of the rumen out through the abdominal incision. To effect the fistula, two layers of sutures are employed, using no. 3 20-day chromic catgut. An underlying row of interrupted sutures

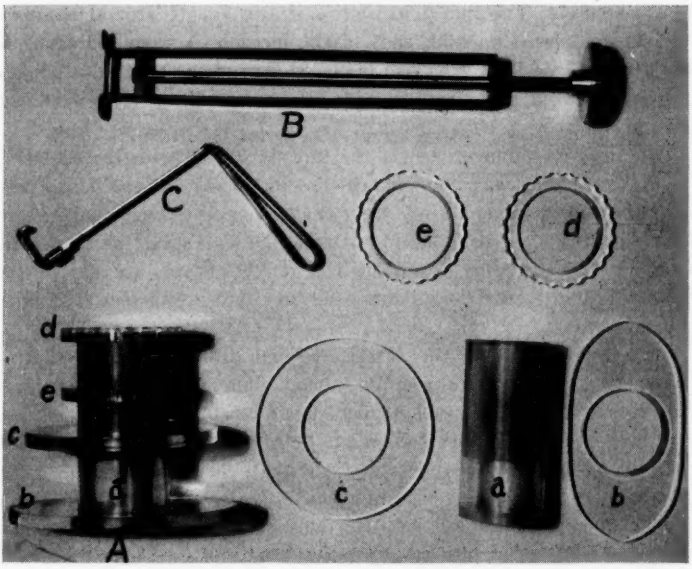


Figure 1. Cannula and installation tools for cows.
A. Cannula assembled.
a. tube.
b. threaded base plate.
c. outer collar, not threaded.
d. screw cap.
e. adjusting ring, threaded.
B. Centering tool.
C. Holding tool.

attaches the peritoneum and muscle layers to the wall of the rumen. A superficial layer fixes the skin and subcutaneous fascia to the rumen wall in the same manner. A vertical incision is then made through the wall of the rumen halfway between the anterior and posterior sutures and approximately 3 ins. in length.

The plastic cannula is then inserted, using the tools shown in figure 1. The base flange is passed edgewise through the opening into the

rumen. The tong end of the centering tool is inserted into the opening and expanded squarely against the threads of the base flange. The tube is then passed over the centering tool into the fistula and engaged into the threads of the base flange. The centering tool is removed, and the holding tool is applied to the base flange while the tube is screwed down securely. The rumen incision is drawn snugly around the tube by sutures placed on both ends of the incision. A wound dressing is then applied, and a cotton pad is placed around the tube. The outside collar is put in place and the adjusting ring tightened to hold the cotton in place.

At times it is difficult to get the threads started with the centering tool. An alternative method for cows is to insert both the base flange and the tube completely into the rumen. A hand is then inserted and the threads are started, the fibrous material supporting the base plate while the tube is being manipulated. After the threads are started, the centering tool is used to withdraw the tube into position in the rumen opening.

After the operation, the cow is fed lightly for about 48–72 hrs. Frequent changes of cotton around the cannula are not desirable, since the eschar is broken at each change. The first cotton should be left on for at least 5–7 days, depending on the condition of the wound, with weekly or bi-weekly changes thereafter until healing is complete. As the swelling subsides, the adjusting ring is tightened to keep the outside collar snug against the skin. After the swelling completely subsides, allowing adequate tightening, any excess length of tube may be cut off.

Cannula Design and Operative Procedure for Sheep

A cannula similar to the one for cows was designed for sheep. The construction of this cannula and tools for installing is shown in figure 2. The dimensions of the component parts are as follows: length of the tube, 7 cm.; inside diameter of the tube, 2 cm.; length of threads on the outer end of tube, 5 cm.; length of threads on base end of the tube, 1 cm.; outside diameter of the tube, 2.9 cm.; length and width of base flange, 10 cm. by 5.1 cm.; diameter of outside collar, 9.0 cm.; outside diameter of adjusting ring and cap, 5 cm. All material has a thickness of 0.9 cm., except for the tube with walls 0.5 cm. thick. For sheep weighing more than 100 lbs. a longer tube may be required.

Prior to the operation, the sheep should be placed on an all-hay ration, with no water for 48 hrs. This reduces the water in the rumen and provides a dry fibrous mat on which to place the base flange for

insertion of the cannula. Since the sheep are restrained in a lateral recumbency, the fluid in the rumen must be kept at a minimum to prevent spillage into the peritoneal cavity during the operation.

Most of the wool is removed from the operative area by shearing. Due to difficulty of removing the remaining wool by shaving, a chemical depilatory is used. Sodium sulfide has been used by others but should

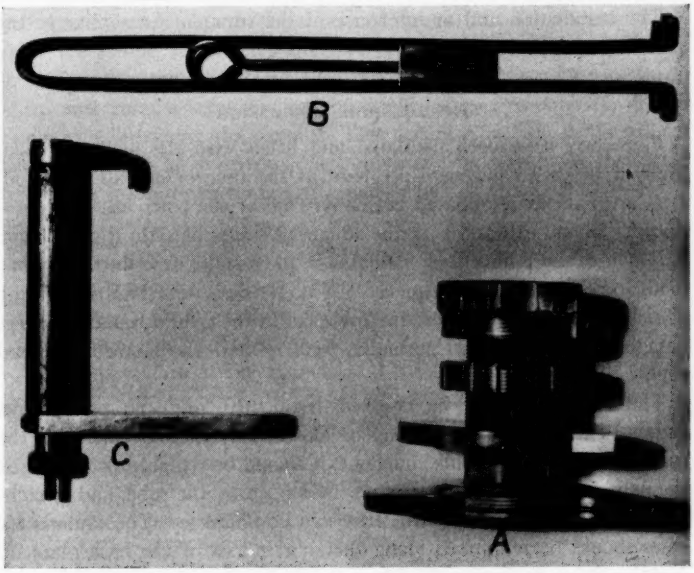


Figure 2. Cannula and installation tools for sheep or goats.
A. Cannula assembled.
B. Centering tool.
C. Holding tool. When passing through the tube, the hinged hook is extended by loosening the thumb nut.

be used with caution to prevent irritation of the skin. A commercial hair remover containing calcium thioglycollate was found effective for removing the wool remaining on the clipped area. The preparation is spread evenly over the operative area and allowed to remain for 10–12 min. and then washed off with soap and warm water. This leaves the area completely devoid of wool, with no apparent harm to the skin.

General anesthesia is employed for the operation. Seventy-five to 150 ml. of a 6 percent solution of chloral hydrate in distilled water are injected into the jugular vein. The quantity required for surgical

anesthesia depends upon the size of the animal and individual susceptibility. The operative technique is the same as for the cow, except for the length of the incisions. The skin incision is about 3 ins. and the rumen incision approximately 2 ins. in length. It is essental in the sheep that the fistula be placed as high as possible in the paralumbar fossa to allow for deviation of the skin from its normal positional relationship during recumbency.

The installation and maintenance of the cannula are similar in the sheep and in the cow.

Results and Discussion

Five cows have been fistulated and fitted with the lucite cannula. Four of the five cows were pregnant at the time of operation and all four pregnancies terminated normally. One of the cows has since produced a second calf and is in the advanced stages of a third pregnancy.

Nineteen sheep have been fistulated in the manner described. Only one died due to operational sequelae. Eight of these were lambs weighing about 60 lbs., and four were mature ewes in their third month of pregnancy. The ewes lambed normally, were re-bred and lambed a second time.

The cannula should be checked frequently, and the base flange tightened if necessary, as it may be loosened by the movements of the rumen. Should the cannula come out, it should be replaced promptly, as the fistula shrinks rapidly when not held open by the tube, and stretching may be required before the tube can be reinserted. The cannula for cows should be reinforced along the shorter axis of the base plate by building it up to greater thickness on the inner surface.

Lucite is hard, nonflexible and strong but is not abrasive to the tissue. It is not attacked by any agents occurring in either the rumen or the tissue. The transparency permits closer observation of progressive healing. Lucite stock is available in various shapes and sizes. It is easily worked on a machine lathe and can be fused together securely by use of organic solvents.

The lucite cannula has some disadvantages as well as many advantages in comparison with the open fistula. The open fistula in the cow permits insertion of the arm for removing large quantities of material, for observing the action of the rumen or for gaining access to the portions of the stomach other than the rumen. For sampling contents with a tube or dipper the plastic cannula provides a more convenient

and easily maintained opening, while restricting movement of gases through the fistula.

In sheep an open fistula is not satisfactory because of excessive spillage, and the described cannula requires a small fistula which limits interference with rumen functions. Because of the small diameter, it is difficult to remove large samples through the cannula. For removal of large quantities, the best procedure is to remove the cap, adjusting ring and washer, and to push the tube and flange into the rumen cavity. After the sample is collected the tube and base flange are pulled back into place and the cannula reassembled.

In most cases a small amount of liquid escapes through the fistula around the outside of the cannula. This occurs especially in the animal whose paunch is large or which is in advanced pregnancy. Spillage may be kept at a minimum by use of a pad or gasket of soft rubber.

Summary

A cannula of lucite, a strong transparent plastic, with a screw cap has been designed for installation in a permanent fistula as a means of gaining convenient access to the rumen.

The construction of the cannula and the operative technique for its installation are described.

It has been used successfully for 1 goat, 5 cows, and 19 sheep.

Literature Cited

Anderson, C. W. and G. H. Wise. 1944. Surgical rumen fistula in the calf. Improved Operative Technique. Jour. Am. Vet. Med. Assoc. 104:20.

Cole, H. H., S. W. Mead and M. Kleiber. 1942. Bloat in cattle. Calif. Agr. Exp. Sta. Bul. 662.

Colin, G. 1886. Traite de Physiologie Comparée des Animaux. Troisieme Ed.: J. B. Baillière et Fils, Paris.

Diernhofer, K. 1928. Demonstration einer Kuh mit kunstlich erzeugter grosser Dauerpansenfistel. Wien. Tierarztl. Monatsschr. 15:481.

Flourens, M. 1833. Experiences sur le Mechanisme de la Rumination. Mem. Acad. Roy. Sci., Inst. France. 12:483.

Phillipson, A. T. and J. R. M. Innes. 1939. Permanent stomach fistulae in ruminants. Quart. Jour. Exp. Physiol. 29:333.

Quin, I. I., J. G. Van der Wath and S. Myburgh. 1938. Studies on the alimentary tract of merino sheep in South Africa. IV. Description of experimental technique. Onderstepoort. Jour. Vet. Sci. Animal Ind. 11:341.

Schalk. A. F. and R. S. Amadon. 1928. Physiology of the ruminant stomach (bovine). Study of the dynamic factor. N. Dakota Agr. Exp. Sta. Bul. 216.

Wester, J. 1926. Die Physiologie und Pathologie der Vormägen beim Rinde. Richard Schoetz. Berlin.

THE EFFECT OF THE CORN-ALFALFA HAY RATIO ON THE DIGESTIBILITY OF THE DIFFERENT NUTRIENTS BY SHEEP

C. A. PHILLIPS, S. D. HARDIN, AND W. E. THOMAS[1]
Kentucky Agricultural Experiment Station

CORN and alfalfa hay are two of the most commonly used feeds for fattening lambs. Just how the proportion of alfalfa hay to corn affects the utilization of the complete ration has not been thoroughly studied.

The feeding of more than 60 percent corn has usually resulted in extensive losses from "feed lot disease" or enterotoxemia, however the development of a successful new vaccine permits the feeding of a more concentrated ration to fattening lambs without abnormal losses (Whitlock and Fabricant, 1947; Baldwin *et al.*, 1948). Culbertson and co-workers (1950) found that a ration containing 80 percent corn produced a better carcass at a greater profit per lamb than did rations containing either 50 or 65 percent corn. These Iowa workers vaccinated the lambs with the bacterin Clostridium perfringens, Type D, and did not encounter difficulty from enterotoxemia.

The present study was designed in an attempt to obtain information on the digestibility of the complete mixture when corn provided 25, 50 and 75 percent of the corn-alfalfa hay rations.

Experimental

The animals used in this experiment were four Southdown X Hampshire-Rambouillet yearling wethers of excellent mutton type. They were selected to be as nearly alike as possible in age, weight, and genetic makeup.

Three rations of cracked yellow corn and chopped alfalfa hay were fed during this study. Ration I consisted of 25% corn and 75% alfalfa; Ration II, 50% corn and 50% alfalfa; and Ration III 75% corn and 25% alfalfa. The same ration was fed to all four sheep at the same time, starting with Ration I and continuing consecutively through Ration III.

[1] Graduate students and Assistant Professor of Animal Husbandry, repectively. The data reported herein were taken from two Masters Theses submitted by the senior authors in partial fulfillment of the requirements of the degree of Master of Science at the University of Kentucky. Acknowledgment is made to Dr. R. F. Elliott and Dr. W. P. Garrigus for the direction of this study.
The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

This procedure was followed since it was not feasible to feed a ration containing 50% or 75% corn without gradually adjusting the animals to the more concentrated mixtures. Rations I and II were fed at a level of 2.0 lbs. daily while Ration III was fed at a 1.5 lbs. level. All rations were fed twice daily. The chemical composition of the rations are shown in table 1.

The sheep were kept in metabolism crates during both the eight-day preliminary and the ten-day collection periods. During the collection periods fecal collections were made daily in a modification of the

TABLE 1. COMPOSITION OF FEEDSTUFFS

Item	Dry Matter	Dry Matter Basis					
		Crude Protein	Ether Extract	Crude Fiber	N. F. E.	Ash	Energy
	%	%	%	%	%	%	Cal/Kg
Analyzed							
Corn	87.0	9.3	4.2	3.0	82.2	1.4	4602
Alfalfa	92.3	17.0	1.9	26.2	48.4	6.5	4454
Calculated							
Ration I	91.0	15.1	2.5	20.4	56.9	5.2	4491
Ration II	89.7	13.4	3.1	14.6	65.3	4.0	4528
Ration III	88.3	11.2	3.6	8.8	73.8	2.7	4565

Garrigus-Rusk (1939) bag. All of the feces collected were preserved in a freezer locker until the end of the collection period. The feces were then thawed, thoroughly mixed and a one kilogram sample was placed in a forced draft oven at 60° C. before being ground for laboratory analyses. Previous research at this Station has shown that the loss of nitrogen from sheep feces dried under these conditions is negligible (Forbes and Garrigus, 1948). An aliquot of each day's urine collection was preserved with acid and refrigeration.

Laboratory analyses of feeds and feces were made by methods approved by the Association of Official Agricultural Chemists. Urinary nitrogen was determined by the Kjeldahl method.

Gross energy values were determined on the feed, feces, and urine according to the techniques described in detail by Forbes and Garrigus (1949). Metabolizable energy of the rations was calculated by subtracting from the gross energy of the feed, the energy of the feces, urine, and methane produced by fermentation. The methane production was calculated by using the equation $E=2.41X+9.80$ (Swift *et al.*, 1948)

in which E signifies grams of methane produced and X represents hundreds of grams of carbohydrate digested. Grams of methane were multiplied by 13.18 to convert to Calories.

Results and Discussion

The data in table 2 show that the apparent digestibility of the different nutrients and energy generally increased as the percentage of corn in

TABLE 2. APPARENT DIGESTIBILITY AND METABOLIZABLE ENERGY VALUES OBTAINED WITH WETHERS ON THREE CORN-ALFALFA RATIONS[1]

Sheep No.	Ration No.	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract	Energy	Metabolizable Energy Cal/Kg	Metabolizable Energy %/gross
		%	%	%	%	%	%		
	1	66	68	35	38	80	61	2517	56
1	2	75	72	63	38	87	65	2721	60
	3	83	67	72	53	92	79	3320	73
	1	67	69	45	37	82	51	2077	46
2	2	75	73	64	38	86	68	2836	63
	3	85	74	73	52	93	82	3442	75
	1	62	66	36	33	76	56	2350	52
3	2	73	70	62	37	84	67	2792	62
	3	81	66	72	59	90	78	3318	73
	1	68	70	46	39	81	55	2267	51
4	2	79	75	69	50	89	67	2803	62
	3	86	74	76	61	93	82	3448	76
Average	1	66	68	41	37	80	56	2303	51
Standard Deviation	1	± 2.5	± 1.8	± 5.5	± 2.7	± 2.6	± 4.1	± 183	± 4.1
Average	2	75	73	64	41	86	67	2788	62
Standard Deviation	2	± 2.7	± 2.0	± 3.1	± 6.2	± 2.2	± 1.0	± 48	± 1.0
Average	3	84	70	73	56	92	80	3382	74
Standard Deviation	3	± 2.2	± 4.3	± 1.9	± 4.3	± 1.4	± 2.0	± 73	± 1.6

[1] Nearest whole percent

the ration increased. The only exceptions to this was for crude protein between the 50% and 75% corn levels and crude fiber between the 25% and 50% corn levels.

In order to avoid a sudden change to a highly concentrated ration, all four of the sheep were fed the low, medium and high corn rations consecutively. This procedure would represent common practice and was undoubtedly beneficial in avoiding digestive disturbances in this experiment. The sheep used in this trial were not vaccinated with a bacterin to prevent enterotoxemia but no digestive disturbances were evident when any of the rations were fed.

If one can assume that there were no carry-over effects from one ration to another, that the lambs did not perform differently during the eight week period due to factors other than those being tested, and that the change in level of intake did not affect the digestibility of the rations, then all differences in apparent digestibility are significant except for crude fiber in comparing rations I and II and crude protein in comparing rations II and III.

Summary and Conclusions

In a study of the utilization of corn-alfalfa hay rations, four yearling wethers were each fed each of three mixtures in which corn provided 25%, 50% and 75% of the mixture. Apparent digestion coefficients for dry matter, crude protein, ether extract, crude fiber and nitrogen-free-extracts were determined, as well as metabolizable energy. As the percentage of corn in the ration was increased, the apparent digestibility of the complete ration increased for all the nutrients except crude protein in one instance and crude fiber in another.

On the basis of the results of this trial it appears that high concentrate rations are the more efficiently utilized by sheep.

Literature Cited

Baldwin, E. M. Jr., L. D. Frederick, and J. D. Ray. 1948. The control of ovine enterotoxemia by the use of clostridium perfringens Type D bacterin. Amer. Jour. Vet. Res. 9:296.

Culbertson, C. C., C. W. McDonald, P. S. Shearer, and W. E. Hammond, 1950. Heavy corn feeding in fattening lambs. Iowa State College A. H. Leaflet No. 174.

Forbes, R. M. and W. P. Garrigus. 1948. Application of a lignin ratio technique to the determination of the nutrient intake of grazing animals. JOURNAL OF ANIMAL SCIENCE 7:373.

Forbes, R. M. and W. P. Garrigus. 1949. The digestibility and metabolizability by lambs of a standard ration of alfalfa and corn and one containing cottonseed hulls. Jour. Agr. Res. 78:483.

Garrigus, W. P. and H. P. Rusk. 1939. Some effects of the species and stage of maturity of plants on the forage consumption of grazing steers of various weights. Univ. of Ill. Agr. Expt. Sta. Bul. 454.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tillman and D. C. Meek. 1948. The effect of dietary fat on utilization of the energy and proteins of rations by sheep. JOURNAL OF ANIMAL SCIENCE 7:475.

Whitlock, J. H. and J. Fabricant. 1947. The use of clostridium welchii Type D anaculture in prevention of overeating disease (enterotoxemia) in sheep. Cornell Vet. 37:211.

COBALT METABOLISM STUDIES WITH SHEEP[1]

H. A. KEENER,[2] R. R. BALDWIN[3] AND G. P. PERCIVAL[2, 4]
New Hampshire Agricultural Experiment Station
and General Foods Corporation

COBALT appears to have some function in relation to the synthesis of a nutritional factor by the flora of the rumen, but the exact role is not known. This belief is supported by the fact that cobalt deficiency has been observed only in ruminants. Further support is given by the results of Ray *et al.* (1948) and of Keener *et al.* (1950) which showed that cobalt given orally was much more effective in relieving the deficiency in sheep than that administered by injection. The fact that injected cobalt brings about any response at all, however, calls for an explanation. One logical explanation for this effect is that some cobalt may make its way from the blood stream into the rumen contents. This explanation is not supported by results of Comar *et al.* (1946) with cattle or those of Marston and Lee (1949) with sheep, although the data of Comar and Davis (1947) indicate some possibility of injected cobalt passing from the blood of cattle to the rumen contents.

A related problem has to do with the manner in which cobalt carbonate, a salt which is relatively insoluble in water, functions in relieving cobalt deficiency. Keener *et al.* (1950) found that this compound was effective in relieving the deficiency in sheep but did not determine if its beneficial action took place in the rumen or if it was absorbed from the digestive tract.

One objective of the study reported here was to determine if sufficient cobalt can pass from the blood stream into the rumen contents to explain the response obtained from cobalt injections. The other was to determine if cobalt carbonate goes into solution in the digestive tract as determined by its absorption into the blood stream.

[1] Scientific contribution No. 136 of the New Hampshire Agricultural Experiment Station, Durham.

[2] New Hampshire Agricultural Experiment Station.

[3] Central Laboratories, General Foods Corporation, Hoboken, New Jersey.

[4] The authors gratefully acknowledge the assistance of Mr. A. D. Littlehale in carrying out this work. The animal work was carried out at the New Hampshire Agricultural Experiment Station. The radioactive cobalt compounds were prepared and the activity measurements made in the Central Laboratories of General Foods Corp.

Experimental Procedure

Three sheep which were suffering from marked cobalt deficiency were obtained from the experiment reported by Keener *et al.* (1950) for the study involving the passage of cobalt from the blood stream into the rumen contents. These animals, which were a little over two years of age, were all females with the Hampshire, Cheviot and Dorset breeds being represented by one animal each. These sheep had been fed

TABLE 1. DISTRIBUTION OF LABELED COBALT ADMINISTERED TO COBALT DEFICIENT SHEEP IN SINGLE JUGULAR INJECTION OF 25 MG. HAVING TOTAL ACTIVITY OF 500 MICROCURIES

	Disintegrations per minute per gram fresh weight		
Tissues and materials	No. 49—12 hours	No. 38—18 hours	No. 22—24 hours
Blood	11,750	10,050	8,500
Rumen	1,500	2,100	1,100
Rumen contents	200	250	180
Abomasum contents	210	470	280
Liver	14,400	14,000	19,500
Spleen	2,700	3,200	2,700
Kidney	15,800	19,500	8,600
Gall bladder and bile	32,500	20,400	14,000
Urine	110,000	53,900	21,500
Small intestine	19,200	6,000	5,200
Small intestine contents	15,000	18,000	20,000
Large intestine	6,800	7,400	5,200
Large intestine contents	12,500	25,000	20,500
Muscle			2,000
Lung			4,500

a ration consisting of all they would eat of a low-cobalt grass hay and not over one pound per day of a concentrate mixture composed of nine parts of corn, which was very low in cobalt, and one part non-fat dry milk solids. The deficiency had become so serious, however, that concentrate consumption had practically ceased with all animals and the hay intake was reduced considerably. The usual twice-a-day feeding schedule was followed during this experiment.

Each animal was given in a single intravenous injection 25 mg. of labeled cobalt in the form of the sulfate in aqueous solution and having a total activity of 500 microcuries. One animal was then slaughtered after 12 hours, the second after 18 hours, and the third after 24 hours. The tissues and materials listed in table 1 were sampled for activity measurements.

Two Cheviot ewes were used on the cobalt carbonate absorption experiment. They were obtained from the same experiment as the other sheep but in addition to the same low-cobalt ration, they had been receiving cobalt sulfate orally at the rate of 3.5 mg. of cobalt twice a week for well over a year. They appeared to be normal in every respect. Each animal was given a single dose of radioactive cobalt carbonate orally by means of gelatin capsules. One was given 10 mg. of cobalt having a total activity of 200 microcuries while the other received twice this amount or 20 mg. of cobalt having a total activity of 400 microcuries. Samples of blood, urine, and feces were taken periodically for activity measurements.

The radioactive cobalt used in this experiment was obtained from the Isotopes Branch of the U. S. Atomic Energy Commission, Oak Ridge, Tenn. in the form of cobalt oxide ($Co_3 O_4$). This material was dissolved in a mixture of nitric and hydrochloric acids and the cobalt sulfate prepared by repeated evaporations to dryness in the presence of concentrated sulfuric acid. The cobalt carbonate was prepared from the solution of cobalt oxide in nitric and hydrochloric acids by boiling to near dryness with hydrochloric acid and then adding a slight excess of sodium bicarbonate. The resulting precipitate of cobalt carbonate was filtered, washed repeatedly with distilled water, and dried at 70° C.

The tissues were prepared for activity measurements by wet-ashing weighed samples of approximately 10 gms. with nitric acid. The solutions obtained were diluted to volume and aliquots taken for counting. Two procedures were used for counting duplicate samples. By one procedure the aliquot was evaporated to dryness and ashed in a porcelain counting dish approximately 3 in. in diameter. The residue was then counted by means of an end window Geiger Müller tube with a window thickness of 1.69 mg./cm.^{2} By the second procedure the activity in 5 ml. aliquots was measured by means of a dipping type Geiger Müller counting tube according to the procedure described by Comar and Davis (1947). Since results obtained by the two procedures agreed very closely, average values are given.

Results and Discussion

The distribution of the injected cobalt in the various organs at the time of slaughter is shown in table 1. These data are presented in terms of number of disintegrations instead of actual amounts of cobalt because of the much greater ease with which comparisons are made. These results substantiate the findings of Comar and Davis (1947)

who reported that injected cobalt is eliminated through both the bile and the urine. The high activity of the urine, bile, and intestinal contents as compared to that of the blood also agrees with the finding of these workers that injected cobalt is eliminated very rapidly from the body.

These results indicate that a very small amount of cobalt can pass from the blood stream into the rumen contents, either directly, through the saliva, or by means of regurgitation from the small intestine. The data might be interpreted as suggesting any or all, although the last method appears rather improbable. When one considers that the activity values for the rumen contents are expressed on the fresh weight basis and also that the amount of material involved was rather large, it becomes apparent that the total amount of cobalt present in the rumen contents was greater than one might realize. Since there was about as much cobalt in 24 hours samples as in that taken after 12 hours, it would appear that there would be some build-up in the cobalt concentration in the rumen contents when injections are given daily. If one assumes that the vital function of cobalt is carried out in the rumen, further support is given for the long retention of cobalt by the fact that an animal may remain on a low cobalt diet for several months before the deficiency becomes evident. On the other hand, it should be remembered that the size of the injection given here was 12 times the size of the smallest daily injection which was found by Keener *et al.* (1950) to bring about a very slow recovery. It would not be expected, however, that the amount of cobalt getting into the rumen contents would necessarily be proportional to the amount injected. If one considers all of these factors along with the fact that some cobalt is carried in the low cobalt ration and that the requirement is very low, it appears that cobalt which has been injected into the blood stream can make its way into the rumen contents in sufficient quantities to bring about a slow recovery from the deficiency, if large enough amounts are administered at frequent intervals over a long enough period.

The data from the cobalt carbonate absorption experiment are presented in table 2. The activity values for the blood and particularly for the urine show that cobalt fed in this form can be absorbed. The significance of this fact, however, is not clear as far as the nutritional function of cobalt is concerned. It is probable that cobalt carbonate is changed to the chloride in the abomasum and thus becomes soluble. It might even be changed to some soluble form in the rumen. It is possible, although highly improbable, that some of the cobalt chloride

formed might be regurgitated into the rumen and bring about the response which is obtained when cobalt carbonate is fed to cobalt deficient animals. It also is theoretically possible for the absorbed cobalt to reach the rumen contents from the blood stream as was done by the injected cobalt. The response from feeding this salt to deficient animals, however, was too rapid to support this latter possibility. It is very apparent that further work will have to be carried out before this situation can be understood.

TABLE 2. DISTRIBUTION OF LABELED COBALT ADMINISTERED ORALLY TO NORMAL SHEEP IN THE FORM OF COBALT CARBONATE

Materials	Time after administration hours	Disintegrations per minute per gram fresh weight	
		No. 29 10 mg. Co—total activity 200 microcuries	No. 33 20 mg. Co—total activity 400 microcuries
Blood	Initial	0	0
	12	108	188
	18	140	505
	24	150	636
	36	175	450
Urine	12	3,600	27,000
	24	2,400	13,000
Feces	12	Present	20,000
	18	21,000	41,000
	24	32,000	50,000
	36	57,000	110,000
	48	58,000	65,000

Summary and Conclusions

An experiment was carried out with cobalt deficient sheep to determine if cobalt injected intravenously made its way into the rumen in sufficient quantities to account for the slow recovery normally obtained. A second experiment was conducted to see if cobalt fed in the form of the carbonate, which is relatively insoluble in water, becomes soluble enough to be absorbed from the digestive tract.

Using labeled cobalt in the form of the sulfate, it was found that very small amounts of injected cobalt do reach the rumen contents. It appears that the amount of such cobalt reaching the rumen contents may be adequate under certain conditions to bring about a slow recovery from the deficiency. Labeled cobalt in the form of the car-

bonate was found to be absorbed in appreciable quantities as indicated by its presence in the blood and urine.

Literature Cited

Comar, C. L., G. K. Davis and R. F. Taylor. 1946. Cobalt metabolism studies: Radioactive cobalt procedures with rats and cattle. Arch. Biochem. 9:149.

Comar, C. L. and G. K. Davis. 1947. Cobalt metabolism studies. III. Excretion and tissue distribution of radioactive cobalt administered to cattle. Arch. Biochem. 12:257.

Keener, H. A., G. P. Percival, G. H. Ellis and K. C. Beeson. 1950. A study of the function of cobalt in the nutrition of sheep. JOURNAL OF ANIMAL SCIENCE. 9:404.

Marston, H. R. and H. J. Lee. 1949. Primary site of the action of cobalt in ruminants. Nature 164:529.

Ray, S. N., W. C. Weir, A. I. Pope, G. Bohstedt and P. H. Phillips. 1948. Studies on the role of cobalt in sheep nutrition. JOURNAL OF ANIMAL SCIENCE 7:3.

THE EFFECT OF ALFALFA ASH UPON ROUGHAGE DIGESTION IN SHEEP[1]

R. W. Swift, R. L. Cowan, G. P. Barron, K. H. Maddy and E. C. Grose

The Pennsylvania State College

BURROUGHS and associates (1945) in a rather extensive series of digestion experiments with steers found under the experimental conditions prevailing that ground corn cobs were about 64% as valuable as the grain itself. It was later reported (Burroughs *et al.* 1949a) that soybean oil meal increased the digestion of the dry matter of rations containing 8 or 15% protein, both with and without corn cobs, indicating that factors other than protein intake were responsible. Further work (Burroughs *et al.* 1949b) revealed that efficient utilization of corn cobs could be obtained even with a very low protein intake, provided no starch was fed. When starch formed a part of the ration it was necessary to increase the protein supplement in order to maintain the level of roughage digestion. The addition of starch was found to decrease the apparent digestibility of crude fiber throughout a wide range in protein intake (Burroughs *et al.* 1949c).

A method for studying the effect of various salts and other materials on the digestion of crude fiber in vitro has been described by Burroughs and associates (1950a). In feeding experiments with steers they found that the addition of a water extract or the ash of alfalfa meal very appreciably increased the digestion of the dry matter of a ration containing 45% ground corn cobs (Burroughs *et al.* 1950b). Casein added to a low-protein ration increased the digestibility of roughage, the main source of which was ground corn cobs (Burroughs *et al.* 1950c).

Materials and Methods

Burroughs and his co-workers have logically reasoned that alfalfa ash (or water extract) contains a substance (s) which is essential for optimum nutrition of rumen microorganisms involved in roughage digestion. However, the increase in the apparent digestibility of dry matter and crude fiber reported could conceivably be of no benefit to the animal, if at the same time there occurred an increase in methane production corresponding to the decrease in fecal output. It seemed desirable therefore to extend their work to take into account the urine

[1] Authorized for publication on December 8, 1950 as paper No. 1640 in the Journal Series of the Pennsylvania Agricultural Experiment Station.

TABLE 1. SCHEDULE OF EXPERIMENTATION

Period No.	Sheep Group	Feed		Collection Period			Calorimeter Period		
		Amount Daily		Start	End	No. of sheep used	Start	End	No. of sheep used
		Basal[1]	Ash						
		gm.	gm.						
1	A	760	—	Dec. 30	Jan. 10	2			
2	B	760	—	Jan. 6	Jan. 16	4	Jan. 18	Jan. 20	3
3	A	760	28	Feb. 3	Feb. 14	6			
4	B	760	28	Feb. 10	Feb. 21	4	Feb. 22	Feb. 24	4
5	A	760	—	Mar. 10	Mar. 21	6			
6	B	760	—	Mar. 17	Mar. 28	6	Mar. 29	Mar. 30	4
7	A	760	28	Apr. 14	Apr. 25	6			
8	B	760	28	Apr. 21	May 2	6	May 3	May 5	4

[1] Including 60 gm. of timothy hay.

and methane. No attempt was made to identify any specific substances responsible, the main objective being to establish the validity of the assumption that there was an actual increase in feed energy made available to the animal by the addition of the ash.

A series of feeding experiments was planned (table 1) using two groups of sheep, each group to receive the basal ration for 5 weeks followed by the basal ration and alfalfa ash for 5 weeks, the feeding schedule then being repeated with each group. The ration, designated as the corn cob mix, similar to that used by Burroughs and associates (1950a), was made up as follows: bone meal, 60.0 lb., salt, 10.0 lb., ground corn cobs, 920.0 lb., skimmilk powder 362.1 lb., cerelose 647.9 lb. The ingredients were thoroughly mixed together in a large mixer at a commercial mill.

Considerable difficulty was encountered in getting the sheep to eat the ration. After various attempts to modify it to insure its consumption by the sheep, reasonably good success was achieved by adding to each 1000 gm. of the mixture described above, 50 gm. of mazola oil, and by feeding also 60 gm. of timothy hay daily. These two items thus formed a part of the basal ration. Two ml. of feeding oil containing 3,000 I. U. of vitamin A and 400 I. U. of vitamin D per gm. were fed daily in all periods. The composition of the dry matter of the basal ration is shown in table 2.

TABLE 2. COMPOSITION OF DRY MATTER OF FEED

Feed	Nitrogen	Ash	Ether extract	Crude fiber	N-free extract	Energy per gm.	Carbon
	%	%	%	%	%	cal.	%
Corn cob mix[1]	1.33	4.70	4.81	16.61	63.19	4320	44.74
Timothy hay	1.31	6.12	2.47	32.73	40.75	4457	46.28
Basal ration	1.33	4.81	4.64	17.80	61.54	4330	44.85

[1] Including mazola and feeding oil.

The general procedure as to periods of transition, preliminary feeding and collection indicated in table 1 was similar to that described in an earlier paper (Swift, *et al.* 1950) which involved separate collection of feces and urine. Carbon dioxide and methane production were measured throughout a 48-hour period in the respiration calorimeter. After finishing the basal periods, the sheep were fed the alfalfa ash for three weeks before the next collection periods were begun. A similar interval followed the withdrawal of the ash preceding the following basal period. The work of Burroughs and associates indicates that this length of time is sufficient to insure against possible carry-over effects of the preceding ration. The calorimetric measurements were made on groups of sheep, usually four in a group, so that individual values for methane were not obtained, the values listed in table 4 being the average per day per sheep. Each animal, however, received identical quantities of feed. Feces and urine values, involved in the computation of metabolizable energy were determined for each individual animal during the 11 days preceding the calorimeter period. Similar to the procedure followed in earlier work (Swift, *et al.* 1950), environmental temperature was maintained at 17.5° C. while the sheep were in the respiration calorimeter and as close as possible to this temperature at all other times. The animals were shorn in mid-September, late November, and again early in April. In each case the shearing took place immediately following a collection period. The purpose of the shearing was to maintain the critical temperature and range of thermal neutrality for the sheep as nearly constant as possible.

Alfalfa ash was prepared by burning alfalfa hay in an outdoor fireplace[2] completing the combustion in the electric muffle furnace. About 750 lb. of alfalfa were used resulting in approximately 64 lb. of ash.

Results and Discussion

Four reasonably satisfactory calorimeter periods were completed with the second group of animals although it was apparent throughout the entire experiment that the basal ration was not relished by the sheep. However, it was possible to secure in addition to the calorimetric measurements a total of 18 digestion periods on the basal ration and 22 on the basal ration plus alfalfa ash. Several duplicate determinations on each ration with a given sheep were obtained, each pair of values being averaged to give digestion coefficients for the individual animal. Twelve such values were obtained for each ration and were

[2] Smokehouse equipment, courtesy P. T. Ziegler, Professor of Animal Husbandry.

TABLE 3. DIGESTIBILITY OF RATION CONSTITUENTS

Periods	Feed	Dry matter	Crude protein	Ether extract	Crude fiber	N-free extract	Energy	T.D.N.
		%	%	%	%	%	%	gms.
1, 2, 5, 6	Basal	63.2	48.6	84.5	43.0	69.6	60.9	466
2, 4, 6, 8	Basal+ash	64.6	51.0	86.9	53.8**	70.5	62.3	494**

** $P \leqq 0.01$ for difference from basal.

compared statistically by Student's method (1908). Although the mean digestibility of every ration constitutent was increased by the addition of the alfalfa ash (table 3), only the increase in digestibility of crude fiber was found to be highly significant, (odds 3332 to 1).

The increase in T. D. N. values obtained for the supplemented ration was also found to be significant (odds 430 to 1). Although the alfalfa ash resulted in an increase in digestibility of the crude fiber from 43.0 to 53.8%, the amount of additional energy represented is quite small since the ration contained only 17.80% crude fiber. It is not surprising therefore that the increase in digestible energy was not significant (odds 5 to 1).

No statistical evaluation could be made of the values for methane and metabolizable energy since the individual values listed in table 4 are averages of 3 or 4 sheep, the carbon dioxide and methane being determined as a single value for each group. However, it is clear from table 4 that while there was an appreciable increase in the production of methane in the ash periods, there was also a much larger increase in the metabolizable energy. In other words the effect of the ash was to increase fermentation in the rumen, making available to the animal, after paying for the overhead (methane), distinctly more feed energy. The observed increase in methane production lends support to the interpretation by Burroughs and associates that alfalfa ash furnishes

TABLE 4. METABOLIZABLE ENERGY AND METHANE

Period	Feed	Metabolizable energy per Kg. dry matter	Methane per Kg. dry matter
		Cal.	Cal.
2	Basal	2365	212
4	Basal+ash	2418	231
6	Basal	2205	213
8	Basal+ash	2371	220

inorganic nutrients essential to rumen micro-organisms involved in roughage digestion.

The ration used in these experiments was made up to correspond closely to the one used by Burroughs and co-workers (1950b) working with steers. It was by no means a good ration, serving merely to demonstrate that a poor quality roughage (corn cobs) is made more digestible by alfalfa ash and that a bona fide improvement in nutritive value results. Further study of the physiological aspects of the problem might involve the feeding of timothy hay, with a crude fiber content of more than 30% though it is questionable whether the digestibility (60%) of the crude fiber from timothy hay would be increased.

Summary

In digestion and calorimetric experiments with sheep fed a ration containing about 40.4% ground corn cobs, the apparent digestibility of the crude fiber was significantly increased by the addition of alfalfa ash (from 43.0% to 53.8%). The increase in crude fiber digestibility was accompanied by an increase in methane production which, however, was not large, the net effect of the added alfalfa ash being to increase the amount of feed energy available to the animal.

Literature Cited

Burroughs, Wise, Paul Gerlaugh, A. F. Schalk, E. A. Silver and L. E. Kunkle. 1945. The nutritive value of corn cobs in beef cattle rations. JOURNAL OF ANIMAL SCIENCE 4:373.

Burroughs, Wise, and Paul Gerlaugh. 1949a. The Influence of soybean oil meal upon roughage digestion in cattle. JOURNAL OF ANIMAL SCIENCE 8:3.

Burroughs, Wise, Paul Gerlaugh, B. H. Edgington and R. M. Bethke. 1949b. Further observations on the effect of protein upon roughage digestion in cattle. JOURNAL OF ANIMAL SCIENCE 8:9.

Burroughs, Wise, Paul Gerlaugh, and B. H. Edgington. 1949c. The influence of corn starch upon roughage digestion in cattle. JOURNAL OF ANIMAL SCIENCE 8:271.

Burroughs, Wise, N. A. Frank, Paul Gerlaugh and R. M. Bethke. 1950a. Preliminary observations upon factors influencing cellulose digestion by rumen microorganisms. Jour. Nutr. 40:9.

Burroughs, Wise, Paul Gerlaugh and R. M. Bethke. 1950b. The influence of alfalfa hay and fractions of alfalfa hay upon the digestion of ground corn cobs. JOURNAL OF ANIMAL SCIENCE 9:207.

Burroughs, Wise, L. S. Gall, Paul Gerlaugh and R. M. Bethke. 1950c. The influence of casein upon roughage digestion in cattle with rumen bacteriological studies. JOURNAL OF ANIMAL SCIENCE 9:214.

Student. 1908. The probable error of a mean. Biometrika 6:1.

Swift, R. W., R. L. Cowan, R. H. Ingram, K. H. Maddy, G. P. Barron, E. C Grose and J. B. Washko. 1950. The relative nutritive value of kentucky blue grass, timothy, brome grass, orchard grass, and alfalfa. JOURNAL OF ANIMAL SCIENCE 9:363.

THE EFFECT OF METHIONINE SUPPLEMENTATION UPON THE UTILIZATION OF PEA AND ALFALFA PROTEINS BY SHEEP[1]

EARLE W. KLOSTERMAN, D. W. BOLIN, EARL L. LASLEY AND W. E. DINUSSON

North Dakota Agricultural College

LOOSLI and co-workers (1949) found that methionine was synthesized in the rumen of sheep and goats when urea was fed as the dietary source of nitrogen. The amount synthesized on certain rations, however, apparently is not adequate for maximum utilization of nitrogen. It had previously been demonstrated by Loosli *et al.* (1945) and Lofgreen and co-workers (1947) that methionine supplementation markedly improved the utilization of urea nitrogen by growing lambs. Lofgreen (1947) also reported that egg protein was utilized more efficiently than that supplied by linseed meal and suggested that the quality of protein as fed to lambs may be of importance under certain conditions.

The objective of the experiments presented in this paper was to determine the value of methionine when added to rations containing different amounts and kinds of protein. Miller (1944) reported that methionine reduced the excretion of nitrogen in normal adult dogs fed a protein-free diet. Stevenson *et al.* (1946) also noted a nitrogen sparing action for methionine in the rat. High levels of protein intake were also fed in these experiments since Almquist (1949) had reported that when the amount of total protein supplied in chick rations was increased the amount of methionine required for maximum growth also increased.

Experimental Methods

Eight pregnant, purebred Shropshire ewes of similar weight and age were used in the first experiment which was started at approximately the second month of pregnancy and continued for six weeks. Mature, grade Hampshire ewes were used in the second and third experiments. The ewes in all comparisons were fed a sufficient amount of the experimental rations to maintain their body weights. Thus, the main require-

[1] Contribution from the Department of Animal Husbandry, Agricultural Experiment Station of the North Dakota Agricultural College, Fargo, North Dakota. Published with the permission of the Director of the Station.

ment for protein in these studies was for maintenance with some additional requirement for gestation in the first experiment.

A double reversal design was used in all three studies to determine the effect of supplemental methionine. The experiments were not designed for a direct comparison of the various amounts and sources of protein. In the first two studies four ewes were fed each ration and in the third all eight ewes were fed the alfalfa ration. The composition of the rations fed is presented in table 1.

TABLE 1. COMPOSITION OF RATIONS FED, IN PERCENT

	Experiment I[1]		Experiment II		Experiment III
Component	Low Protein Ration	Pea Ration	Pea Ration	Alfalfa Ration	Alfalfa Ration
Grass hay	50.73	51.97	—	—	—
Wheat straw	—	—	40.82	16.56	—
Dehydrated alfalfa	—	—	—	46.36	81.97
Dried beet pulp	32.73	30.11	—	—	—
Cerelose	15.04	—	6.80	15.88	—
Field peas	—	16.62	30.61	—	—
Molasses	—	—	20.41	19.88	16.39
DiCalcium phosphate	0.75	0.65	0.68	0.66	0.82
Salt[2]	0.75	0.65	0.68	0.66	0.82
Total	100.00	100.00	100.00	100.00	100.00
Total protein, percent air dry basis	6.16	9.59	9.87	10.12	15.48

[1] Ewes were fed hay according to appetite, composition is average fed for three periods.
[2] Salt used in experiment I was a trace mineral salt which contained: manganese, 0.45%; iodine, 0.019%; cobalt, 0.013%; iron, 0.48%; and copper 0.048%. Iodized salt was fed in experiments II and III.

Preliminary and collection periods of seven days each were used. During the periods of methionine feeding approximately 0.15 percent DL methionine[2] was added to each ration in experiments I and II and 0.30 percent in experiment III.

The L methionine content of the rations, feces and urine for experiments II and III were determined microbiologically. One-half gram of material was hydrolyzed with 10 ml. of 1.2 N.HC1 for 10 hours in an autoclave at 15 pounds pressure. The organism used for these determinations was *Leuconostoc mesenteroides* P-60 #8042.

Values for metabolic and endogenous nitrogen excretion as deter-

[2] The methionine used in these experiments was generously supplied by the Dow Chemical Company, Midland, Michigan.

mined by Harris and Mitchell (1941) were used for the calculation of true digestibility and biological value of protein.

Results and Discussion

The results of three nitrogen balance experiments are presented in tables 2, 3, and 4. As would be expected a close relationship was found

TABLE 2. NITROGEN BALANCE DATA ON DAILY BASIS—EXPERIMENT I

Items	Low protein ration		Pea ration	
	Control	Plus DL-methionine	Control	Plus DL-methionine
No. of observations	6	6	6	6
Nitrogen intake, gms.	10.79	11.57	20.50	21.40
Nitrogen intake, gms. per kilo	0.20	0.21	0.37	0.37
Nitrogen absorbed, gms.	4.44	4.32	11.21	11.71
Urinary nitrogen, gms.	2.93	2.76	8.47	7.79
Nitrogen retained, gms.	1.51	1.56	2.74	3.92
Nitrogen retained, as percent of intake	13.97	13.45	13.38	18.31
Nitrogen retained, as percent of absorbed	33.97	36.03	24.47	33.48
Apparent digestibility of nitrogen, percent	41.13	37.34	54.70	54.71
True digestibility of nitrogen, percent	86.4	83.8	86.6	86.8
Calculated biological value of protein	88.0	90.0	62.6	68.5
Biological value adjusted for nitrogen intake per kilo	70.8	76.2	65.8	72.0

between nitrogen intake and the calculated biological value of protein. When the seventy-two determinations obtained in the three experiments were grouped together a significant negative correlation ($r=-0.80$) was found between nitrogen intake per kilogram per day and biological value. A second degree curve, which gave a significantly better fit than a straight line, was fitted to these data and the biological values were adjusted for nitrogen intake per kilogram per day. As the nitrogen intakes in some of the comparisons between the control and plus-methionine rations were not identical the adjusted biological values are also presented.

TABLE 3. NITROGEN AND L METHIONINE BALANCE DATA ON DAILY BASIS—EXPERIMENT II

Items	Pea ration		Alfalfa ration	
	Control	Plus DL-methionine	Control	Plus DL-methionine
No. of observations	6	6	6	6
Nitrogen intake, gms.	18.67	19.11	18.45	19.22
Nitrogen intake, gms. per kilo	0.35	0.35	0.33	0.34
Nitrogen absorbed, gms.	11.01	11.10	10.00	11.09
Urinary nitrogen, gms.	10.23	10.10	7.63	7.39
Nitrogen retained, gms.	0.78	1.00	2.37	3.70
Nitrogen retained as percent of intake	4.20	5.25	12.87	19.27
Nitrogen retained as percent of absorbed	7.13	9.04	23.75	33.38
Apparent digestibility of nitrogen, percent	59.0	58.1	54.2	57.71
True digestibility of nitrogen percent	89.9	88.7	85.5	87.9
Calculatel biological value of protein	50.2	50.8	63.3	67.1
Biological value adjusted for nitrogen intake per kilo	52.2	53.7	63.7	68.5
L-methionine intake, gms.	0.68	1.08	0.93	1.20
L-methionine excreted, gms.	0.48	0.47	0.48	0.48
L-methionine retained, gms.	0.20	0.61	0.45	0.72

TABLE 4. NITROGEN AND L METHIONINE BALANCE DATA ON DAILY BASIS—EXPERIMENT III

Items	Alfalfa Ration	
	Control	Plus methionine
No. of observations	12	12
Nitrogen intake, gms.	28.90	28.90
Nitrogen intake, gms. per kilo	0.52	0.53
Nitrogen absorbed, gms.	20.00	20.03
Urinary nitrogen, gms.	15.41	15.53
Nitrogen retained, gms.	4.59	4.50
Nitrogen retained as percent of intake	15.87	15.57
Nitrogen retained as percent of absorbed	22.93	22.47
Apparent digestibility of nitrogen, percent	69.20	69.30
True digestibility of nitrogen, percent	89.2	89.4
Calculated biological value of protein	47.3	46.9
Biological value adjusted for nitrogen intake per kilo	51.9	52.0
L-methionine intake, gms.	1.86	2.86
L-methionine excreted, gms.	0.43	0.42
L-methionine retained, gms.	1.43	2.44

Due to a low nitrogen intake high biological values were obtained in experiment I when the ewes were fed a ration of grass hay, dried beet pulp, cerelose and minerals. The addition of 0.15 percent DL methionine to this ration brought about only a slight improvement in nitrogen retention and biological value. It would appear that the nitrogen intake was sufficiently low on this ration that nearly maximum utilization was made of the available nitrogen with or without supplemental methionine. The nitrogen intake on the ration with methionine added was slightly higher than on the control ration. When the biological values were adjusted for this difference there appeared to be greater value from the supplemental methionine.

When field peas, a source of protein deficient in methionine, were added to the low protein ration a more marked improvement in nitrogen retention and utilization was noted from the addition of methionine.

The rations used in experiment II were compounded with wheat straw, cerelose and black strap molasses so that a high proportion of the available nitrogen in the rations came from either field peas or dehydrated alfalfa. The composition of the two rations and the amounts fed were calculated so that the daily intake of protein, fiber and energy from the pea and alfalfa rations were approximately equal.

It is apparent from the data presented in table 3 that the supplemental methionine brought about little or no improvement in the utilization of field pea protein in this experiment. The added methionine, however, did increase nitrogen retention of the alfalfa ration. The difference between the biological values of the alfalfa ration and the same ration with methionine added was significant at the 5 percent level.

Even though the pea and alfalfa rations were not fed to the same sheep it is of interest to note the considerable difference in nitrogen retention and biological values of these two rations. It is difficult to compare the biological value of a concentrate and a roughage. It will be noted from table 3, however, that the nitrogen intake and the amount of nitrogen absorbed were very similar on these two rations. The amount of nitrogen retained was considerably higher on the alfalfa ration and the difference in biological value was significant at the 1 percent level. It is also noteworthy that the ewes fed the pea ration (9.87 percent total protein) retained less nitrogen than those fed the low protein ration (6.16 percent protein) in experiment I.

The low biological value obtained for the pea ration in experiment II apparently was not due to a simple methionine deficiency since a supplement of this amino acid brought about no significant improvement. When field peas were fed with grass hay and dried beet pulp in

experiment I a considerably higher biological value was obtained which was also increased significantly by the addition of 0.15 percent DL-methionine. It should be noted that in addition to other differences in the pea rations used in experiments I and II that a trace mineral salt was used in experiment I and iodized salt was fed in experiment II. Gall and co-workers (1949) found a simpler flora and lower bacterial count in the rumen of cobalt deficient sheep and those fed the same ration with a cobalt supplement. Burroughs *et al.* (1950) reported that a complex mineral mixture was a most potent supplement which greatly increased rumen microbiological digestion of poor quality roughage. Burroughs and co-workers (1950) also demonstrated that a water extract or the ash of dehydrated alfalfa meal improved the digestion of corn cobs. The differences in mineral make up of the two pea rations and the alfalfa ration used in these experiments may have been of importance in the differences in protein utilization which resulted.

The L-methionine intake, excretion and retention values obtained in experiment II are presented in table 3. DL-methionine was added to the supplemented rations but only the L isomer was determined microbiologically. Thus, the difference in total methionine intake between the control and supplemented rations was greater than the values presented in table 3. The amount of L-methionine excreted was that which was present in the feces as no measurable amount of the amino acid was found in the urine. It will be noted that the amount of the amino acid excreted was the same whether or not the ewes received supplemental methionine. It would appear that the L-methionine added to the ration was either completely utilized or destroyed which resulted in an apparent higher retention on the supplemented rations.

The ration used in experiment III was composed of dehydrated alfalfa, cane molasses and minerals and contained 15.48 percent protein on a 10 percent moisture basis. Molasses was included in this ration primarily as a carrier for the supplemental methionine and also to reduce the dustiness of the ration. In this experiment 0.30 percent DL-methionine was added to the supplemented ration. From the data presented in table 4 it it apparent that the addition of methionine brought about no improvement in the utilization of the protein in this ration. It will be noted that the L-methionine intake on the ration used in this experiment was higher than on the alfalfa ration used in experiment II. These data indicate that the methionine intake on this high protein, alfalfa ration was adequate for the maximum utilization of protein by mature ewes without a supplement of this amino acid.

The amount of L-methionine excreted in the feces in experiment III was very similar to the amount excreted in experiment II when the ewes received one-half the amount of L-methionine intake. It will be noted from the data presented in tables 3 and 4 that the apparent digestibility of nitrogen was somewhat higher in experiment III than on the alfalfa ration used in experiment II. This difference in digestibility of protein between the two experiments may partially explain the apparent higher retention of L-methionine in experiment III.

Inasmuch as the apparent digestion coefficients obtained were slightly lower than average values as reported by Morrison (1948) it is possible that the molasses reduced the digestibility as was demonstrated by Briggs and Heller (1940, 1945). However, since the same amount of molasses was used in the control and plus-methionine rations any effect of this factor may be disregarded.

The combined data obtained from the three experiments were analyzed statistically. The difference between the adjusted biological values of the control rations and the same rations with DL-methionine added was significant at the 5 percent level. The greatest part of this difference was due to the addition of methionine to the rations used in experiment I and the alfalfa ration fed in experiment II. The differences between the biological values of the five rations listed in table 1 was significant at the 1 percent level after they had been adjusted for differences in the amount of nitrogen consumed per kilogram of body weight daily. Possible reasons for the differences between rations and differences in response to supplemental methionine have been discussed.

Summary

The results of three double reversal, nitrogen balance experiments conducted with mature ewes are presented. These experiments were designed to determine the effect of methionine supplementation upon the utilization of various amounts and sources of protein.

When the results of the three experiments, in which five different rations were studied, are considered the addition of DL-methionine significantly increased nitrogen retention. The supplemental methionine had considerably greater effect when added to certain rations than when added to others. Possible reasons for these differences are discussed.

L-methionine intake and excretion values were determined microbiologically in two of the experiments. The results of these analyses indicated that the supplemental methionine was either completely utilized or destroyed.

When fed at approximately the same level of protein intake dehydrated alfalfa had a significantly higher biological value than field peas. The data presented suggest that some factors other than the level of protein intake or amino acid make-up influenced the utilization of protein in these experiments.

Literature Cited

Almquist, H. J. 1949. Amino acid balance at supernormal dietary levels. Proc. Soc. Exp. Biol. Med. 72:179.

Briggs, H. M. and V. G. Heller. 1940. The effect of adding blackstrap molasses to a lamb-fattening ration. Jour. Agr. Res. 60:65.

Briggs, H. M. and V. G. Heller. 1945. Tolerance of lambs for blackstrap molasses. Jour. Agr. Res. 71:81.

Burroughs, Wise, Paul Gerlaugh and R. M. Bethke. 1950. The influence of alfalfa hay and fractions of alfalfa hay upon the digestion of ground corn cobs. JOURNAL OF ANIMAL SCIENCE 9:207.

Gall, L. S. 1949. Effect of ration upon rumen flora of cattle and sheep. JOURNAL OF ANIMAL SCIENCE 8:619.

Harris, L. E. and H. H. Mitchell. 1941. The value of urea in the synthesis of protein in the paunch of the ruminant. I. In Maintenance. Jour. Nutr. 22:167.

Lofgreen, G. P., J. K. Loosli and L. A. Maynard. 1947. The influence of protein source upon nitrogen retention by sheep. JOURNAL OF ANIMAL SCIENCE 6:343.

Loosli, J. K. and L. E. Harris. 1945. Methionine increases the value of urea for lambs. JOURNAL OF ANIMAL SCIENCE 4:435.

Loosli, J. K., H. H. Williams, W. E. Thomas, F. H. Ferris and L. A. Maynard. 1949. Synthesis of amino acids in the rumen. Science 110:144.

Miller, L. L. 1944. The metabolism of DL-methionine and L-cystine in dogs on a very low protein diet. Jour. Biol. Chem. 152:603.

Morrison, F. B. 1948. Feeds and Feeding, 21st Edition. The Morrison Pub. Co., Ithaca, N. Y.

Stevenson, G., P. P. Swanson, W. Willman and M. Brush. 1946. Nitrogen metabolism as influenced by level of caloric intake, character of diet and nutritional state of animal. Proc. Fed. Am. Soc. Exp. Biol. 5:240.

EFFECT OF STAGE OF MATURITY AND STORAGE ON QUALITY, QUANTITY, AND NUTRITIVE VALUE OF SOUTH DAKOTA PRAIRIE HAYS[1, 2]

GEORGE E. STAPLES, R. M. JORDAN, GEO. F. GASTLER, ARNOLD B. NELSON[3] AND C. J. FRANZKE

South Dakota Agriculture Experiment Station

IN much of the Northern Great Plains area native grasses are of paramount importance to livestock production and hays from these grasses constitute the chief roughage harvested to maintain livestock when grazing will not support them. Tonnage of prairie hay harvested in South Dakota in 1948 and 1949, a total of 4,492,000 tons, was twice as great as the harvested tonnage of all tame hays combined.

A common practice in harvesting prairie hay has been to arrange haying operations to interfere least with other summer work. In following such practice, many stockmen have done the bulk of their haying from late September until winter weather interfered. Many ranchers believe that any loss in quality by late harvesting is offset by a greater yield per acre.

A need was seen to test representative native hays to determine the effect of stage of maturity on feeding value and digestibility of such hays and to study the nutritive value of hay stacked under range conditions and stored over a period of years. Since droughts often prevent the production of hay for harvest, the successful stockman must harvest enough hay during productive years to carry over the dry years.

Work done at other stations indicates that hay harvested late in the season has lost much of the nutritive value that could have been obtained if the hay had been harvested at an earlier date. Hopper and Nesbitt (1930) reported that both stage of maturity and grass species influenced chemical composition and nutritive value of hays and grasses. Declines in chemical composition and/or nutritive value as stage of maturity in grasses advanced were noted by Burkitt (1940), Sotola (1941), Patton and Gieseker (1942), Patton (1943), McCall, Clark, and Patton (1943), McMillen *et al.* (1943), Crampton and Jackson (1944), and Baker *et al.* (1947).

[1] A contribution from the Animal Husbandry Department. Approved for publication by the Director of the South Dakota Agriculture Experiment Station. Publication No. 258 of the Journal Series.

[2] Supported in part by a grant from Swift & Co., Chicago, Ill.

[3] Formerly Assistant Animal Husbandman South Dakota Agr. Exp. Station; present address Oklahoma A. & M.

Briggs, Gallup, and Darlow (1948) reported decrease in total digestible nutrients per pound of hay as maturity advanced and also a decrease in the amount of total digestible nutrients produced per acre.

Gastler and Moxon (1943, 1944) in testing two grass species from eleven areas in South Dakota found that the protein and mineral content declined as the stage of maturity advanced.

TABLE 1. AVERAGE CHEMICAL COMPOSITION OF REPRESENTATIVE PRAIRIE HAYS USED IN DIGESTION TRIALS AND FEEDING EXPERIMENTS

Hay	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	Nitrogen-free Extract %
Eureka 1947					
Early-Cut	85.64	7.08	2.75	27.98	39.49
Medium-Cut	85.76	5.74	2.84	29.26	39.63
Late-Cut	84.94	4.17	2.96	30.16	39.24
Eureka 1948					
Early-Cut	91.30	7.09	2.56	29.40	41.67
Medium-Cut	91.32	6.60	2.64	29.42	43.69
Late-Cut	91.79	4.75	3.10	30.37	43.64
Storage Hay (2-Years old)	91.44	8.35	2.60	29.84	41.04
Highmore 1948[1]					
Early-Cut	81.19	7.52	2.20	26.83	36.53
Medium-Cut	83.89	6.50	2.91	27.80	38.31
Late-Cut	74.26	3.56	2.76	25.27	35.50

[1] Analyses taken from hays used in digestion trial. These hays were in a severe snow storm immediately following baling and contained some "ice spots' which accounts for the low percentages of dry matter.

The hays used in this study were prairie hays cut from three widely separated areas within the state. The major species were western wheatgrass (Agropyron smithii), three species of needlegrass (Stipa spartea, S. comata, and S. viridula) big bluestem (Andropogon furcatus) and little bluestem (Andropogon scoparius). Other species appearing in lesser but varying amounts included blue grama (Bouteloua gracilis), side-oats grama (B. curtipendula), junegrass (Koeleria cristata), downy brome (Bromus tectorum), buffalograss (Buchloe dactyloides) and various forbs.

The hays were cut at three different stages of maturity to determine the effects of stage of maturity on chemical composition and nutritive value. The first hay, designated "early-cut," was harvested, usually before mid-July, at the "shooting" stage, characterized by the grass

shooting up the seed stalk preparatory to seed formation. The second hay was cut at the "seed-ripe" stage and designated as "medium-cut," and usually was harvested near mid-August. The third hay, designated "late-cut," was harvested between September 20 and October 10, at a fully mature stage with most of the seeds and some leaves having fallen. The hay designated as "storage" hay was harvested near an early-cut stage of maturity and stored over a period of years to test the effect of long-time storage on the nutritive value.

Chemical Analysis

Table 1 shows the chemical composition of representative hays, harvested in the Eureka and Highmore areas, that were used in the digestion trials and winter feeding experiments. These hays were analyzed according to A.O.A.C. standard methods. From this table it can be seen that the protein decreased as the stage of maturity increased. The protein content of the hay cut at an early stage of maturity and stored for two years remained high. This indicates that there was little or no loss of protein due to storage under conditions encountered in these trials.

Digestion Studies

Both steer calves and wether lambs were used in the digestion trials with from three to nine animals of each species per trial (Table 2 A & D, 9 animals per hay, 2 B, 6 animals per hay, and 2 C, 3 animals per hay). The total collection method was used with preliminary and collection periods each of 10 days duration for trials A, C, and D, and 10 and 7 days respectively for trial B.

The feces from both lambs and steers were collected in canvas sacks similar to those described by Forbes (1937). The coefficients of digestibility were determined in the manner outlined by Maynard (1947).

The digestion studies were made on hays from the Eureka and Highmore areas and a summary of the results is given in table 2. A perusual of the data for trials A and B, when only hay was fed, shows that for dry matter, crude protein, and nitrogen-free extract apparent digestibility decreased as the maturity of the hay increased. The greatest relative decrease was for crude protein. For ether extract and crude fiber there were some exceptions to a general decrease in apparent digestibility with increased maturity. When rations, made up of hay supplemented with oats and soybean oil meal, were fed there was less regularity in differences between results from various hays though the

TABLE 2. AVERAGE COEFFICIENTS OF APPARENT DIGESTIBILITY OF DIFFERENT QUALITIES OF PRARIE HAY

Hay and test animals	Dry Matter	Crude Protein	Ether Extract	Crude Fiber	Nitrogen-free Extract
	%	%	%	%	%
A—Eureka Hay 1947[1]					
Early Cut					
Steers	47.61	43.96	50.81	55.20	50.88
Lambs	47.86	51.38	31.61	58.27	52.81
Medium Cut					
Steers	44.25	31.31	36.55	53.00	48.18
Lambs	41.82	32.48	30.16	50.16	47.18
Late Cut					
Steers	38.38	6.75	32.09	48.88	42.56
Lambs	41.27	23.04	23.27	51.99	44.41
B—Eureka Hay 1948[1]					
Early Cut					
Steers	46.51	41.14	29.11	62.95	47.99
Lambs	40.55	34.38	19.12	54.03	43.10
Medium Cut					
Steers	42.76	29.80	21.98	56.62	46.66
Lambs	40.25	30.35	15.34	55.38	42.36
Late Cut					
Steers	40.51	11.88	37.39	56.96	43.79
Lambs	37.90	12.56	34.81	55.28	39.92
2 Yr. Storage Early Cut					
Steers	46.44	45.98	34.60	59.26	47.04
Lambs	44.29	40.86	46.77	52.76	47.00
C—Cureka 1947[2]					
Steers					
Early Cut	50.01	60.92	55.10	57.79	54.85
Medium Cut	52.01	55.27	33.77	59.59	54.86
Late Cut	47.53	45.78	54.46	56.28	49.92
D—Highmore 1948[2]					
Steers					
Early Cut	50.04	61.58	40.98	54.26	54.03
Medium Cut	50.70	63.99	41.22	52.78	55.97
Late Cut	43.03	56.00	40.06	44.36	49.54

[1] Ration fed consisted of hay only.
[2] Rations fed consisted of the appropriate hay plus one pound of oats and one pound of soybean oil meal per head daily.

general trend was for the late-cut hay ration to have the lowest digestibility.

Apparent digestibility of crude protein, the constituent among the five studied most likely to be deficient in prairie hays, decreased with maturity in all cases except one, namely 1948 Highmore hay (table 2 D) when medium-cut hay plus supplement had the highest digestibility. The coefficients of digestibility of crude protein ranged from a high of 45.98 for early-cut to a low of 6.75 for late-cut when fed to steers and 51.38 to 12.56 for lambs when only hay was fed. On the rations of hay plus supplements the range was from a high of 63.99 for the ration with early-cut hay to a low of 45.78 for the ration with late-cut hay for steers. This would indicate that when the hays were supplemented with oats and soybean oil meal and the medium- and late-cut hays were improved more in digestibility than the early-cut hay. However, it did not make the ration containing late-cut hay equal to the one containing early-cut hay.

Feeding Trials

A series of winter feeding trials was conducted with the various hays. One trial was with mature beef cows and the remainder were with calves with an initial weight of about 400 pounds. The trial with cows was conducted at Reed Ranch in 1947–48 with early-, medium-, and late-cut hay and one-year-old storage hay. The cows that received early and medium-cut hay made daily gains of 0.66 pound and 0.15 pound per head respectively while losses of 0.53 pound and 0.24 pound per head daily were recorded for those on late-cut hay and year-old storage hay.

The same winter (1947–48) at the Cottonwood Station three lots of calves were fed in drylot as follows: lot I early-cut hay; lot II medium-cut hay; lot III late-cut hay. One pound of oats and one pound of 40 percent soybean oil meal per calf were fed daily in all lots. The average daily gains were 0.95, 0.68, and 0.34 pound in lots I, II, and III respectively.

The next two winters, 1948–49 and 1949–50, trials were started at the Cottonwood, Eureka, and Highmore Stations but because of unfavorable weather conditions not all trials were completed. The rations were the same as those reported above and in addition various storage hays were tested. A summary of the results is presented in table 3.

If the data from table 3 and the two earlier trials are combined it is evident that the highest winter gains were obtained from early-cut hay, and the poorest from late-cut hay with the difference being greater

between medium-cut and late-cut than betwen early-cut and medium-cut. In terms of feed required for each hundredweight of gain the data show a slight superiority for medium-cut over early-cut and both of these being much superior to late-cut. The results from the storage hays

TABLE 3. AVERAGE DAILY GAINS AND FEED REQUIRED PER HUNDRED POUNDS OF GAIN FOR CALVES WINTERED ON EARLY-, MEDIUM-, LATE-CUT, AND STORAGE HAYS PLUS SUPPLEMENT[1]

Results from Highmore, Cottonwood, and Eureka Stations 1948–49 and 1949–50

Comparison		Early cut hay[2]	Medium-cut hay[2]	Late-cut hay[2]
Average daily gain	lb.	1.08	1.06	0.72
Feed offered per 100 lb. gain				
Hay	lb.	1089.6	1074.5	1481.1
Protein supplement	lb.	99.8	96.5	130.1
Oats	lb.	102.3	98.9	133.6

Comparison		1-yr. old storage hay[3]	2-yr. old storage hay[4]	3-yr. old storage hay[5]
Average daily gain	lb.	1.02	0.74	1.40
Feed offered per 100 lb. gain				
Hay	lb.	1109.8	1344.2	867.4
Protein supplement	lb.	95.6	103.9	57.6
Oats	lb.	100.1	137.4	57.6

[1] Equalized feeding of each type of hay plus 1 pound of oats and 1 pound of soybean oil meal per calf daily.
[2] Tested on 8 animals in 1948–49 and on 8 and 10 animals in 1949–50.
[3] Tested on 8 animals in 1949–50.
[4] Tested on 8 animals each year.
[5] Tested on 10 animals in 1949–50.

are not consistent but these were different hays cut in different years and not in all cases early-cut. However, the results do indicate that hays can retain a relatively high feeding value after storage.

Comparative Yields Per Acre

Many producers have the idea that what hay loses in quality is made up in quantity by letting the grass become more mature before cutting. Studies on yields in connection with the feeding and digestion trials have produced results contrary to this belief. Yield was calculated by

cutting ten random plots 34 inches by 20 feet from each cutting in each area tested. Yields from these plots were weighed, samples taken and dried, and dry matter yield calculated for each plot. The average yield of dry matter was then calculated on a per acre basis. Table 4 shows a three station average for early-, medium-, and late-cut hays in producing pounds of dry matter per acre during 1948 and 1949. These yields of dry matter were obtained at the Cottonwood, Eureka, and Highmore Stations.

The data in table 4 indicate that yields of dry matter per acre decline as the grass matures. The lower yield of the more mature hays is attributed to the loss of seeds and some leaves as the stage of maturity advances.

TABLE 4. POUNDS OF DRY MATTER PER ACRE FOR HAY CUT AT EARLY, MEDIUM, AND LATE STAGES
(3-Station Average)

Year	Early	Medium	Late
	lbs.	lbs.	lbs.
1948	1150	1025	971
1949	1376	899	743

Summary

During the three years 1947–48 to 1949–50 chemical analyses have been made of hays cut at various stages of maturity, namely; early-cut (usually from early- to mid-July) medium-cut (mid-August), late-cut (late-September to early-October) and early- to medium-cut that has been stored for a varying number of years. Feeding trials with cattle, and digestion trials with sheep and cattle, were conducted to study further the nutritive content and feeding value of these hays. From this work the following conclusions were drawn.

1. Protein content of hay was affected materially by time of harvest. Late-cut hay contained only 50 to 70 percent as much total protein as early-cut hay.

2. Dry matter, ether extract, crude fiber, and nitrogen-free extract were not affected seriously by time of harvest.

3. The time at which hay was cut affected the apparent digestibility of the nutrients in the hay. The digestibility of protein showed the greatest decrease as maturity of the hay advanced whereas the digestibility of dry matter, nitrogen free extract, ether extract, and fiber were reduced only slightly when late-cut hay was fed as compared to early-cut hay.

4. Adding a supplement of oats and soybean oil meal to the hays improved the digestibility of the medium- and late-cut hay rations to a relatively greater extent than the early-cut hay ration.

5. Early- and medium-cut hay produced greater animal gain and lower feed consumption per hundred pounds of gain than late-cut hay when all hays were supplemented with one pound of oats and one pound of 40 percent soybean oil meal per calf daily.

6. Storing native hay in stacks for as long as three years did not appear to reduce its nutritive value.

7. Yearly yields of early-cut hay, during a two-year period from three stations, averaged over 400 pounds more dry matter and about 50 pounds more protein per acre than did late-cut hay.

Literature Cited

Official and tentative methods of analysis. Association of Official Agricultural Chemists 1940. Fifth Edition, Wash., D. C.

Baker, M. L., V. A. Arthaud, E. C. Conrad and L. C. Newell. 1947. Effects of time of cutting on yield and feeding value of prairie hay. Nebr. Expt. Sta. Bul. 385.

Briggs, H. M., W. D. Gallup, and A. E. Darlow 1948. The yield and feeding value of prairie hay as related to time of cutting. Okla. Agr. Expt. Sta. Bul. B-320.

Burkitt, W. H. 1940. The apparent digestibility and nutritive value of beardless wheatgrass at three stages of maturity. Jour. Agr. Res. 61:471.

Crampton, E. W. and I. R. C. Jackson. 1944. Seasonal variation in chemical composition of pasture herbage and the relation to its digestibility by steers and sheep. (Pasture Studies XXVI) JOURNAL OF ANIMAL SCIENCE 3:333.

Forbes, E. B., J. W. Bratzler, A. Black and W. W. Brannan. 1937. The digestibility of rations by cattle and sheep. Penn. Agr. Exp. Sta. Bul. 339.

Gastler, G. F. and A. L. Moxon. 1943. Protein content of grasses at different stages of growth. S. Dak. Agr. Expt. Sta. Chem. pamphlet #1.

Gastler, G. F. and A. L. Moxon. 1944. Calcium and phosphorus content of grasses at different stages of growth. S. Dak. Agr. Expt. Sta. Chem. pamphlet #2.

Hopper, T. H. and L. L. Nesbitt. 1930. The chemical composition of some North Dakota pasture and hay grasses, N. Dak. Agr. Expt. Sta. Bul. 236.

McCall, R., R. T. Clark, and A. R. Patton. 1943. The apparent digestibility and nutritive value of several native and introduced grass. Mont. Agr. Expt. Sta. Tech. Bul. 418.

McMillen. W. N., Q. Williams, and W. Langham 1943. Chemical composition, grazing value and vegetative changes in a typical plains pasture. JOURNAL OF ANIMAL SCIENCE 2:237.

Maynard, L. A. 1947. Animal Nutrition. McGraw Hill Book Co., Inc., New York and London.

Patton, A. R., and L. Gieseker. 1942. Seasonal changes in the lignin and cellulose content of some Montana grasses. JOURNAL OF ANIMAL SCIENCE 1:22.

Patton, A. R. 1943. Seasonal changes in the lignin and cellulose content of some Montana grasses II. JOURNAL OF ANIMAL SCIENCE 2:59.

Sotola, Jerry. 1941. The chemical composition and apparent digestibility of nutrients in smooth brome grass harvested at three stages of maturity. Jour. Agr. Res. 63:427.

GENETIC AND ENVIRONMENTAL FACTORS AFFECTING TYPE AND CONDITION IN NAVAJO AND NAVAJO CROSSBRED WEANLING LAMBS[1]

G. M. Sidwell, D. A. Price and J. O. Grandstaff[2]
U. S. Departments of Agriculture and the Interior

INVESTIGATIONS underway at the Southwestern Range and Sheep Breeding Laboratory at Fort Wingate, New Mexico are conducted with the aim of improving mutton qualities and wool production in Navajo and Navajo crossbred sheep. Rigorous culling of the lambs is done shortly after weaning. At this time several environmental factors may tend to conceal genetic merit, and corrections or adjustment for these environmental effects increases the accuracy of selection.

Hazel and Terrill (1945, 1946) working with range Rambouillet, Columbia, Corriedale and Targhee weanling lambs found that nearly all of the environmental factors studied had important effects on one or more weanling traits. Bonsma (1939) in South Africa found that growth rates of several breeds of lambs and breed crosses were influenced by sex, age of dam and type of birth. Starke (1945) also working in South Africa found difference in body type and condition due to sex and type of birth.

The purpose of this study was (1) to measure the importance of several environmental factors as they affect body type and condition (degree of fatness) in weanling lambs, and (2) to obtain estimates of differences in type and condition between lambs produced in the several breeding groups maintained in the breeding program at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico. The environmental factors studied were year of birth, age of dam, type of birth and rearing, sex and age of lamb at weaning. The breeding groups studied were:

1 Navajo Rams x Navajo Ewes
2 Romney Rams x Navajo Ewes
3 Columbia Rams x Navajo Ewes
4 Lincoln Rams x Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
5 Cotswold Rams x Ewes ½ Navajo, ¼ Corriedale, ¼ Romney

[1] The data for this study were collected at the Southwestern Range and Sheep Breeding Laboratory, Fort Wingate, New Mexico, under authority of the Bankhead-Jones Act, by the Bureau of Animal Industry, U.S.D.A. in cooperation with the Bureau of Indian Affairs, U. S. Department of Interior, and the New Mexico Agricultural Experiment Station.

[2] James O. Grandstaff is an employee of the U. S. Department of the Interior who is also collaborating with the U.S.D.A.

6 Rams ½ Cotswold, ¼ Navajo, ⅛ Corriedale, ⅛ Romney x Ewes ½ Columbia, ½ Navajo
7 Rams ½ Columbia, ½ Navajo x Ewes ½ Cotswold, ¼ Navajo, ⅛ Corriedale, ⅛ Romney
8 Rams ½ Lincoln, ¼ Navajo, ⅛ Corriedale, ⅛ Romney x Ewes, ½ Romney, ½ Navajo
9 Rams ½ Romney, ½ Navajo x Ewes ½ Lincoln, ¼ Navajo, ⅛ Corriedale, ⅛ Romney
10 Targhee Rams x Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
11 Merino Ram x Ewes ½ Navajo, ¼ Corriedale, ¼ Romney
12 Debouillet Ram x Ewes ½ Navajo, ¼ Corriedale, ¼ Romney

Description of Data

The data used in this study were taken on a total of 1673 lambs, representing all lambs weaned in 1948 and 1949. Since all lambs weaned in the two years were included in the study, the data are free from all effects of selection except for death that occurred prior to weaning. The lambs were born in May both years and weaned at an average age of about 120 days. Type and condition scores were taken at weaning time by a committee of two experienced animal husbandmen working independently. The final score for each lamb is the average of the two scores. The scoring system was the same for both traits; lambs considered as having the highest merit were given a score of 1 and those of lowest merit a score of 5. By assigning plus and minus values to each whole unit, a scoring range of 15 units was obtained.

Method of Analysis

The number of lambs weaned are listed in table 1 according to their various classifications. The numbers 1 to 12 in the first column of table 1 indicate the various breeding groups as outlined previously in this report. The method of analysis used is the least squares method suggested by Yates (1934) and extended by Hazel (1946) and Henderson (1948). This method was designed for the application of analysis of variance to data in which multiple classification with unequal numbers in the different classes is encountered. This method consists in fitting constants for each of the independent variables, which in this case are the measurable environmental factors and the different breeding groups. Table 2 shows that for type scores, years and sex were not significant; therefore, new least square equations were solved leaving out these two sources of variations. The new estimates of the deviations with the non-significant constants eliminated are found in

TABLE 1. NUMBERS OF LAMBS WEANED, ASSEMBLED ACCORDING TO BREEDING, AGE OF DAM, SEX, TYPE OF BIRTH AND REARING, AND YEARS

Breeding Group	Age of Dam				Sex		Type of Birth and Rearing			Years	
	2 years	3 years	4–7 years	8 years & older	Rams	Ewes	Singles	Twins	Twins raised as singles	1948	1949
1	50	0	113	93	138	118	91	129	36	132	124
2	17	95	131	1	121	123	118	99	27	127	117
3	22	45	169	0	105	131	112	94	30	115	121
4	45	60	195	35	159	176	153	141	41	251	84
5	29	35	109	9	88	94	84	75	23	96	86
6	61	62	0	0	55	68	65	42	16	34	89
7	63	45	0	0	53	55	76	22	10	30	78
8	36	0	0	0	17	19	27	8	1	0	36
9	16	0	0	0	10	6	12	0	4	0	16
10	0	6	66	1	42	31	27	41	5	0	73
11	0	3	28	2	16	17	16	10	7	0	33
12	0	3	26	2	16	15	8	17	6	0	31

TABLE 2. SUMMARY OF ANALYSIS OF VARIANCE FOR ENVIRONMENTAL FACTORS AND BREEDING GROUPS

(Mean Squares Only)

Source of Variation	Degrees of Freedom	Type	Condition
Total	1672		
Reduction Due to Fitting All Constants	19		
Between Breeding Groups	11	4.60**	2.23**
Between Ages of Ewes	3	5.70**	3.64**
Between Sexes	1	0	4.33**
Between Types of Birth and Rearing	2	50.91**	29.77**
Between Years	1	0.08	5.68**
Between Ages at Weaning	1	20.12**	9.00**
Remainder	1653	0.141	0.163

** Indicates highly significant mean squares.

TABLE 3. SUMMARY OF ESTIMATES OF DEVIATIONS FROM MEAN SHOWING THE VALUE FOR EACH SUBCLASS OF THE MAJOR CLASSIFCATION

Major Classification	Subclass	Estimate of Deviations		
		Type		Condition
		Original	Non-Significant constant eliminated	Original
Breeding Groups	1	.44	.44	.34
	2	.04	.04	.06
	3	.08	.08	.06
	4	—.06	—.06	—.01
	5	—.01	—.02	.09
	6	—.06	—.06	—.06
	7	—.08	—.08	—.02
	8	—.24	—.23	—.14
	9	—.14	—.14	—.08
	10	—.02	—.02	—.12
	11	—.07	—.06	—.15
	12	.10	.11	.03
Age Group of Ewes	2 years	.06	.06	.01
	3 years	—.05	—.05	—.04
	4 to 7 years	—.18	—.18	—.14
	8 years & older	.17	.17	.17
Sex	Rams	—.02		.05
	Ewes	.02		—.05
Type of Birth and Rearing	Singles	—.24	—.24	—.18
	Twins	.32	.32	.25
	Twins raised as singles	—.08	—.08	—.07
Years	1948	—.01		—.07
	1949	.01		.07
Age of Lamb at Weaning in Days	Regressions of type and condition on age	—.02	—.02	—.01

table 3. Of these new constants, only those for breeding groups 5, 8, 11 and 12 were changed.

Results

Tables 2, 3 and 4 summarize the pertinent data concerning variations in the two traits studied. Table 3 shows the estimates of the deviations from the mean for each subclass of the six major classifications for both traits. It should be noted that negative differences reflect superior merit in both traits. The means for type and condition are 2.59 and 2.48, respectively. When the deviations in table 3 are added to the means the actual values for the score for each subclass can be seen.

TABLE 4. PERCENTAGE OF TOTAL VARIANCE ATTRIBUTED TO EACH MAIN SOURCE OF VARIATION

Main Source of Variation[1]	Type	Condition
Total Environmental Effect	50.8	35.4
Breeding Group	10.6	5.9
Age of Dam	3.6	2.6
Sex		1.0
Type of Birth and Rearing	21.4	14.3
Years		1.4
Age at Weaning	4.2	2.2
Remainder	49.2	64.6

[1] The difference between the percentages for the total environmental effect and the sum of the main sources of variation, 11.0 for type and 8.0 for condition, is attributable to two or more of the main factors, but cannot be analyzed more completely because of the unequal subclass numbers.

Body Type

Table 2 shows that for body type, all sources of variation except that due to years and sex were highly significant. Type of birth and rearing accounted for the largest percentage of the total variance (table 4) in these data. Single lambs were scored 0.56 better in type than twins and 0.16 better than twins raised as singles. Twins raised as singles were scored 0.40 better than twins. The next largest difference as measured by percentage of the total variance was between breeding groups. Ewes 4 to 7 years of age raised lambs superior in type to the other three age groups studied. Scores for body type improved with age at weaning as indicated by regression of type on age at weaning. Approximately 50 percent of the total variation in body type could be attributed to the factors studied. Hazel and Terrill (1945, 1946) reported about 18 percent of the variance was accounted for in the environmental factors studied in range Rambouillet lambs and 22 percent in Columbia, Corriedale and Targhee lambs.

Condition

Differences due to all sources of variations studied were highly significant for condition or degree of fatness. Single lambs were scored .43 better in condition than twins and .11 better than twins raised as singles. Age of dam was also an important source of variation. Scores for degree of fatness improved with age until the dams reached an age of 8 years and older. Ram lambs had slightly poorer scores than ewe lambs. With the exception of sex and one of the breeding groups all environmental factors and breeding groups varied in the same direction for condition scores as they did for type scores. Approximately 35 percent of the total variation was accounted for in the factors studied.

Breeding Group Differences

Table 3 shows the differences between breeding groups for body type and condition scores. Navajo lambs were scored poorest for these two traits. Debouillet sired lambs were next poorest in body type followed by lambs sired by Columbia and Romney rams and out of Navajo ewes. The lambs scored highest in merit for body type were those having an inheritance of 3/8 Navajo, 1/4 Lincoln, 5/16 Romney and 1/16 Corriedale. Although not considered as environmental variations, breeding group differences made up about 11 percent of the total variation in type scores and 6 percent of the variation in condition scores.

Discussion

Of the total variation in body type and condition a considerable amount, 50 percent in type and 65 percent in condition scores, still remains unexplained. How much of this variance may be due to factors that cannot be readily measured and how much is due to genetic causes have yet to be determined. If most of this unexplained variation is due to hereditary causes then genetic progress from selection will be rapid. However, if adjustments or corrections are made for the known environmental factors then more accurate selections can be made and more rapid improvement expected. Thus for body type, a twin lamb 110 days of age in a flock averaging 120 days and born of a 2 year old mother would have .58 subtracted from its original score [—.32—.02 (120–110)—.06=—.58].

Adjustments for sex need not be made if ram lambs are not compared with ewe lambs when selections are made. However, progeny tests can be evaluated more accurately if records are adjusted for sex. This is particularly true if the number of lambs in the different groups is small.

Summary

The effects of breeding groups, sex, age of dam, year of birth, type of birth and rearing and age of lambs at weaning on body type and condition scores were studied on 1673 lambs weaned in 1948 and 1949. The average age at weaning was about 120 days.

The advantage of body type scores for single lambs over twin lambs was 0.56. Lambs from 4 to 7 year old dams were superior in type scores to lambs from 2 year old dams, 3 year old dams and dams 8 years and older by 0.24, 0.13 and 0.35, respectively. Differences in body type scores for years and sex were not significantly different.

Ewe lambs were scored better for condition than ram lambs, and single lambs had superior scores to twin lambs or twins raised as singles. Ewes 4 to 7 years of age produced lambs having more condition than either of the other groups studied. Merit in both type and condition scores improved with age at weaning as indicated by regression coefficients.

The factors studied accounted for about 50 percent of the total variance in body type and 35 percent in condition, "or degree of fatness." If the more important differences due to environmental factors are considered in culling lambs, more accurate selection can be made, resulting in more rapid improvement from selection.

Literature Cited

Bonsma, F. N. 1939. Factors influencing the growth and development of lambs, with special reference to cross-breeding of Merino sheep for fat-lamb production in South Africa. Univ. Pretoria Pub. Series I: Agri. No. 48, 214 pp.

Hazel, L. N. and C. E. Terrill. 1945. Effects of some environmental factors on weaning traits of range Rambouillet lambs. JOURNAL OF ANIMAL SCIENCE 4:331.

Hazel, L. N. and C. E. Terrill. 1946. Effects of some environmental factors on weanling traits of range Columbia, Corriedale and Targhee lambs, JOURNAL OF ANIMAL SCIENCE 5:318.

Hazel, L. N. 1946. The covariance analysis of multiple classification tables with unequal subclass numbers. Biometrics Bul. 2:21.

Henderson, C. R. 1948. Information regarding the analysis of nonorthogonal data. Personal Commun.

Starke, J. S. 1945. Grade Southdown sires for sucker-lamb production. Farming in South Africa, 19:553.

Yates, F. 1934. The analysis of multiple classification tables with unequal numbers in the different classes. Jour. Amer. Stat. Assn. 29:51.

A STUDY OF CROSSBREEDING SHEEP

K. P. Miller and D. L. Dailey
University of Minnesota[1]

MOST crossbreeding experiments reported have used rams of various breeds in matings to Rambouillet ewes. One of the earliest of these reports was by Miller (1935) who found that crossbred lambs from Rambouillet ewes and Suffolk, Hampshire and Shropshire rams grew faster and had a higher appraised value at 3½ to 4 months of age than lambs sired by Rambouillet rams. Southdown- and Romney-sired lambs were lighter, but the Southdown lambs had a higher appraised value than the Rambouillet sired lambs. Shropshire and Southdown rams sired lambs of highly desirable carcass quality, but the Suffolk and Hampshire rams sired the fastest growing lambs that had the highest appraised value. Hultz *et al.* (1935) used rams of six different breeds on range ewes. The lambs sired by Suffolk rams grew fastest, followed by Hampshire, Lincoln, Rambouillet, Corriedale and Southdown sired lambs, in that order. Lambs from Rambouillet ewes and Columbia rams were heavier than those sired by Corriedale, Lincoln, or Romney rams at 140 days of age, according to Gorman *et al.* (1942). The ewes bred to Lincoln rams had the highest productivity followed by those bred to Corriedale, Romney and Columbia rams, in that order. This difference in productivity was due largely to a difference in survival of the lambs. Horlacker (1933) observed that Ryeland X Cheviot lambs weighed 10 pounds more than purebred Cheviot lambs at 84 days of age. This difference was attributed to differences in breed size, heterosis, and the fact that more of the purebred lambs were twins.

Since there is little in the literature reporting crosses using ewes of the mutton breeds, and since the flocks at the several University of Minnesota branch stations were already on a record of performance breeding program as outlined by Winters *et al.* (1946), it seemed desirable to test these breeds in crossing. The grade Rambouillet ewe has

[1] North Central Experimental Station, Grand Rapids, Minnesota.

become popular among Northern Minnesota sheepmen. It was desirable to compare the performance of these ewes with the mutton breeds and to determine what breed rams crossed most successfully with these Rombouillet ewes, under northern Minnesota conditions.

Experimental

This study reports 1295 matings made at the four University branch stations during the years 1942–47. Seven hundred forty of these were purebred matings of the Shropshire, Hampshire, and Columbia breeds. Five hundred fifty-five crossbred matings were made, involving 17 different combinations. Shropshire ewes were mated to Columbia, Oxford, Targhee, Hampshire, and Border Leicester rams. Some of the Hampshire ewes were mated to Oxford rams and a few Oxford ewes were mated to Shropshire rams. The Columbia ewes were mated to Hampshire, Suffolk, Shropshire and Targhee rams and the Grade Rambouillet ewes were bred to Oxford, Shropshire, Hampshire, Cheviot, Columbia and Border Leicester rams. The Rambouillet ewes were grade Montana ewes of the type commonly called western White-faced ewes, that clip fine and half-blood fleeces. The purebred Shropshire flock at each station was used as a basis for comparison since all stations had Shropshire flocks. These flocks had all been bred for performance a number of years before crossing began. Comparisons were made with other purebreds when available, and with the various crosses. It was not possible to make comparisons between all breeds used in crossing and purebreds of that breed. Conditions varied between the four stations. Environment, feeding, lambing dates, and scoring varied to the extent that comparisons between stations cannot be made, hence direct comparisons are made only between matings at each station for each year. Productivity was calculated according to Winters *et al.* (1946) as follows:

$$\text{Productivity per 100 lb. ewe} = \frac{100 \times \text{lb. Lamb} + (\text{Lb. grease wool} \times 3.4)}{\text{Weight of ewe}}$$

The lambs were weighed at birth and at 140 days of age. Wool was corrected by the factor 3.4, because it was found that over an 18-year period, a pound of wool sold for 3.4 times as much on the Boston wool market as a pound of lamb at South St. Paul. The ewe weight is an average of two weights taken on November 1st and June 1st each

production year. Average productivity is production of all ewes bred, whether they lambed or not.

All lambs were given a numerical score when they were weighed at 140 days of age. This score ranged from 1 to 5, with 1 being top market grade and 5 being a cull.

Results

Table 1 is a comparison of all purebred matings with crossbred matings for the Columbia, Shropshire, and Hampshire. When used for crossing, the ewes produced 12% to 22% more lamb per 100 pounds of ewe than when lambing purebred lambs. This increase averaged 19% and was due to faster growth rate in the case of the Shropshire crosses and the greater number of crossbred lambs raised per ewe for all crosses. The Columbia and Hampshire ewes had a slightly higher lambing percentage when bred to a ram of another breed. The death loss among the purebreds was greater in all cases; 27.4% of the purebred lambs born alive did not live to 140 days of age, compared to 19.1% for the crossbred lambs. When total productivity is figured, the ewes had 16% greater productivity when used in crossing, compared to ewes lambing purebred lambs.

The Crossbred Shropshires and Columbia lambs scored higher than the purebreds. For this particular character, the Columbias gained most from crossing.

Winters *et al.* (1946) pointed out that ewes' productivity is increased most when mated to rams of the larger breeds. This point is further born out by the much greater growth rate for the Shropshire crosses compared to no increase in rate of growth for the Columbia and Hampshire crosses. The Columbia and Hampshire crosses were by smaller breeds, yet the lamb weights were as high as the purebreds.

A possible heterosis effect is suggested by the greater number of crossbred lambs born alive per ewe for the Hampshire and Columbia crosses. No figures are available on lambs born dead, but fetal mortality may have been higher for the purebreds. The slightly lower lambing percentage for the Shropshire ewes used in crossing may partially be explained when we note that the average age of the ewes lambing crossbred lambs was only slightly over two years, whereas those lambing purebred lambs averaged almost three years.

The Rambouillet ewe performed very satisfactorily when compared to the Shropshire; especially when mated to Border Leicester rams. This

TABLE 1. UNIVERSITY OF MINNESOTA CROSSBRED SUMMARY 1942–1947

Breeding of lambs	Ewes	Ewe Wts.	Wool	Lambs per Ewe		Lamb Weights		Grade	Prod. per 100 lb. Ewe		
				Born	20 wks.	Birth	20 wks.		Wool	Lambs	Total
	Number	Pounds	Pounds	Number		Pounds			Pounds		
Shrop x Shrop	563	129	7.6	1.44	1.16	8.0	60	1.96	5.9	54	74
Shrop crosses	253	130	9.0	1.38	1.21	9.5	71	1.81	6.9	66	90
Col x Col	111	159	13.2	1.66	1.31	9.4	82	2.55	8.3	68	96
Col crosses	67	160	13.5	1.74	1.54	9.4	80	2.09	8.4	77	103
Hamp x Hamp	43	185	8.3	1.61	.96	9.5	71	1.00	4.5	37	52
Hamp crosses	12	186	8.7	1.75	1.17	9.6	71	1.00	4.7	45	61
Ave. P. B.	717	158	9.7	1.57	1.14	9.0	71	1.84	6.2	53	74
Ave. Crossbred	332	159	10.4	1.62	1.31	9.5	74	1.63	6.7	63	86
% Cross of P. B.			107.0	103.00	115.00	106.0	104	106.00	108.0	119	116

comparison is shown in table 2. Rambouillet ewes were mostly two-year olds at lambing, whereas the Shropshires were mostly three and four-year olds. This may explain the difference in lambs born per ewe. In every other respect, the Rambouillet excelled the Shropshire. The Rambouillet ewes sheared 30%, or about 2 pounds, more wool than the Shropshires, although the latter ewes were several pounds heavier. The death rate of the purebred Shropshire lambs was 21%, and for the Rambouillet crosses, 12%.

The lambs from the Rambouillet ewes weighed 13 pounds more than the purebred Shropshire lambs at 140 days of age. The Rambouillet lambs scored almost one grade higher on the average than the purebreds. These lambs were larger at birth, more vigorous and better able to take care of themselves than the purebred lambs.

The Rambouillet ewes produced, per 100 pounds, 50% more wool than the Shropshire and 20% more lamb than the Shropshires lambing purebred lambs. The total productivity was 27% more than the Shropshire ewes, even though the fertility was only 78% of the Shropshire. These ewes had less trouble lambing, were not subject to wool blindness and were less likely to be caught by bears than the Shropshire ewes.

A comparison between the different breed rams is shown in table 2. Performance was highest when the Rambouillet ewes were mated to Border Leicester rams. The Columbia, Oxford, and Hampshire were also over 20% heavier than the purebred Shropshire lambs. The Cheviot lambs lacked weight at 140 days, but were all well finished, had excellent livability, and were easy to raise. Of the six different breed rams tried on Rambouillet ewes, the Shropshire ranked sixth.

Summary

1. Shropshires, Columbias, and Hampshires produced 19% more lamb per 100 lbs. of ewe when mated to another breed. The average total productivity was 16% more for the ewes used in crossing. The crossbred lambs were heavier and had higher livability than the purebreds.
2. This increase in productivity was likely due to heterosis and difference in breed size.
3. The Rambouillet ewe was 27% more productive, when used in crossing, than the Shropshire ewe mated to a Shropshire ram. This greater productivity was due to more wool and faster growing lambs.

TABLE 2. RAMBIOULLET WHEN USED IN CROSSING COMPARED TO P.B. SHROPSHIRE NORTH CENTRAL STATION 1942–46

Breeding of Lambs	Ewes	Av. Wt. of Ewes	Wool	Lambs per Ewe Born/20 Wks.		Lamb Weights Birth/20 Wks.		Grade	Production per 100# of Ewe Wool	Lamb	Total
	Number	Pounds	Pounds	Number		Pounds				Pounds	
Shrop x Shrop	46	135	6.4	1.54	1.47	8.3	60	2.0	4.7	65	81
Col x Ramb	17	116	8.7	1.16	1.13	11.1	72	2.0	7.5	70	96
% of P.B. Shrop		86	136.0	75.00	77.00	134.0	120	100.0	160.0	108	119
Shrop x Shrop	44	113	6.2	1.34	.75	8.1	53	3.0	5.5	36	55
Oxf x Ramb	20	133	9.6	1.20	.80	10.1	66	2.0	7.2	41	66
% of P.B. Shrop		118	155.0	90.00	107.00	125.0	125	133.0	131.0	114	120
Shrop x Shrop	101	140	7.6	1.53	1.37	8.3	58	3.0	5.4	57	75
Shrop x Ramb	47	104	8.9	1.04	.94	10.1	63	2.0	8.6	57	86
% of P.B. Shrop		74	117.0	68.00	69.00	122.0	109	133.0	159.0	100	115
Hamp x Ramb	35	101	8.8	1.03	.94	10.7	72	2.0	8.7	67	97
% of P.B. Shrop		72	116.0	67.00	69.00	129.0	124	133.0	161.0	118	129
Shrop x Shrop	171	129	7.5	1.53	1.14	8.3	55	3.0	5.8	49	69
Chev x Ramb	84	113	9.4	1.31	1.19	9.0	59	2.0	8.3	62	90
% of P.B. Shrop		88	125.0	86.00	104.00	108.0	107	133.0	143.0	127	130
Shrop x Shrop	159	130	7.6	1.54	1.16	8.0	55	3.0	5.8	49	69
Leic x Ramb	64	114	9.7	1.24	1.12	10.0	72	2.0	8.5	71	100
% of P.B. Shrop		88	128.0	81.00	97.00	125.0	131	133.0	147.0	145	145
Ave. Shrop x Shrop		129	7.1	1.50	1.18	8.2	56	2.8	5.4	51	70
Ave. Ramb Crosses		114	9.2	1.16	1.02	10.2	67	2.0	8.1	61	89
Ave. % P.B. Shrop		88	130.0	78.00	87.00	124.0	120	128.0	150.0	120	127

4. Border Leicester, Hampshire, and Columbia rams sired the fastest growing lambs when mated to Rambouillet ewes. However, the Border Leicester crosses resulted in the largest total productivity and resulted in the greatest advantage over the Purebred and Shropshire matings.

Literature Cited

Gorman, J. A., F. S. Hultz, O. G. Hankins, and D. A. Spencer. 1942. Crossbreeding for lamb and wool production. Wyo. Agr. Exp. Sta. Bul. 254.

Horlacker. L. J. 1933. A comparison of the growth of purebred Cheviot and crossbred Byeland X Cheviot lambs. (Abstract) Proc. Amer. Soc. An. Prod. p. 163.

Hultz, F. S., J. A. Gorman, S. S. Wheeler. 1935. Crossbreeding with Western ewes. Wyo. Agr. Exp. Sta. Bul. 210.

Miller, Robert F. 1935. Crossbreeding investigation in the production of California spring lambs. Calif. Exp. Sta. Bul. 598.

Winters, L. M., D. L. Dailey, O. M. Kiser, P. S. Jordan, R. E. Hodgson, and W. W. Green. 1946. Factors affecting productivity in breeding sheep. Minn. Agr. Exp. Sta. Tech. Bul. 174.

CHANGES IN THE HORMONE CONTENT OF SWINE PITUITARIES DURING THE ESTRUAL CYCLE

G. E. Robinson, Jr., and A. V. Nalbandov
University of Illinois

IN an extensive study conducted at the University of Illinois during the past few years qualitative and, where possible, quantitative data on the anatomic, endocrine and genetic causes of sterility and impaired fertility of female swine have been obtained (Wilson, Nalbandov and Krider, 1949). In addition to a large number of partially or completely sterile females a group of presumably normal females was studied. The past reproductive performance of these normal control animals was accurately known, permitting us to obtain some interesting correlations between the hormone content of their pituitaries and the ovarian changes of each animal during the normal estrual cycle.

That a cyclic variation of the gonadotrophic and thyrothrophic hormone content of the pituitary exists among animals has been amply shown in endocrine literature. Wolfe (1931) found swine pituitaries to be most potent during proestrum and least potent during heat. Similar results for swine were obtained by Faermark and Singerman (1938). Studies with females from other species support the conclusion that the gonadotrophic potency of pituitaries from animals in estrus is lower than during the remainder of the cycle. But no systematic attempt has been made in earlier studies to correlate assayable potency of the pituitary throughout the estrual cycle with the ovarian activity of the donor. Such a study of normal females, it seemed, might further the understanding of the role of this gland in sexual development and function, and could be used as a standard for comparison with females with impaired fertility.

The object of this study was to measure the day-by-day changes in the gonadotrophic and thyrotrophic activity of normal swine pituitaries during the 21-day estrual cycle. This study was also designed to show the simple and multiple correlations between (1) day of cycle and number of follicles, (2) day of cycle and gonadotrophic potency, (3) number of follicles and gonadotrophic potency, (4) day of cycle and pituitary weight, (5) day of cycle and number of corpora lutea and (6) day of cycle and thyrotrophic potency.

Materials and Methods

The pituitaries used in this study were obtained from nulliparous and multiparous females which had shown normal estrual cycles prior to being killed. Statistical analysis revealed that there were no significant differences between nulliparous (gilts) and multiparous (sows) females as far as follicle size and number (follicle index) and the number of corpora lutea were concerned. There was no significant difference between the gonadotrophic potency of identical amounts of pituitary powder from the two ages. In view of the significantly heavier pituitaries found in sows the total amounts of gonadotrophic and thyrotrophic hormone present per gland were much greater in sows than in gilts. Due to the larger body weight of the sows the amount of gonadotrophic hormone per unit body weight was found to be about the same in the two age groups. For these reasons it appears proper not to differentiate between these two types of females in the subsequent discussion, especially since they are distributed at random throughout the different days of the estrual cycle. The differences in pituitary weights between the animals of different ages were taken into account in the statistical analysis.

The animals were permitted to go through at least two complete cycles after being placed on experiment and prior to being killed. Heat periods were established by the use of teaser males. The pituitaries were removed from the heads 15 to 30 minutes after the animals had been killed. Individual glands were placed into small vials, properly numbered, and kept frozen until they were ready for use. In all cases a careful description was made of the ovaries of each female, including the number and diameters of all visible follicles and the number of corpora lutea or corpora albicantia.

Day-old male chicks were chosen as assay animals because, in addition to being suitable test animals for both hormones in which we were interested, it was possible to run the two assays simultaneously on the same animal. The response of the two end-points to the hormone is probably independent of each other. The chicks used were of the Single Comb White Leghorn breed and were received at the laboratory the day following hatching. During injections they were kept in standard chick brooders and were fed an adequate growing ration.

The glands were allowed to thaw just before they were to be used for assay and the pituitary stalk and the adhering connective tissue were removed. Each pituitary was weighed after trimming, placed between two glass plates and flattened by an appropriate amount of

pressure. The glass plates with the adhering mangled gland were placed in a calcium chloride desiccator at room temperature for dehydration which was completed in about 24 hours.

The dry glands were ground into a fine powder which was stored in a calcium chloride desiccator until ready for use a few days later. The exact amount of powder to be injected was suspended in distilled water and this aqueous suspension was kept in the refrigerator during the period of injections. Each pituitary was assayed individually.

Preliminary tests showed that 10 mgs. of swine pituitary powder produced a good response for both hormones to be measured. Since most of the glands yielded a little more than 30 mgs. of powder, it was decided to let the amount of powder obtained determine the number of chicks to be used for each gland. The birds were two to three days old at the time of the first injection. A total of 10 mgs. of pituitary powder per chick was injected subcutaneously in eight equal doses during four days. At each injection, the chick received the powder suspended in 0.25 ml. of water. The animals were sacrificed on the fifth day, their testes and thyroids were removed, cleaned, fixed in Bouin's solution and later weighed. The increments in the weights of the testes and thyroids of the injected chicks compared with those of the uninjected controls were used as the criteria of hormone effects.

In order to reduce errors due to differences in season, assay animals, and other environmental causes, the pituitaries were assayed in series. Each series included at least one pituitary for each day of the cycle for which glands were available; thus glands representing the early and late portions of both the follicular and luteal phases of the cycle were assayed simultaneously. Two complete series consisting of glands distributed throughout the cycle were run while the third series consisted of glands representing only days-1, -2, -6, and -13 of the cycle. No significant differences were found to exist between these series and they were therefore combined. For each series an adequate number of uninjected control chicks was retained.

It was found most advantageous in this laboratory to date the estrual cycle of the sow beginning with the first day of heat which was called day-1 of the cycle. Ovulation is known to occur on the second or third day of heat depending on the age of the female. On the basis of uterine histology the luteal phase extends to the thirteenth day of the cycle (eleventh day after ovulation) while the follicular phase begins on the fourteenth day and includes the first and second days of the new cycle (Green, 1950).

In order to correlate the ovarian activity of the donor with the gonadotrophic hormone content of her pituitary a quantitative description of the ovary had to be devised. A simple follicle count was not thought adequate because late in the follicular phase and early in the luteal phase about the same number of follicles was found in the ovaries but those in the follicular phase were much larger than the ones in the luteal phase (table 1). Tabulation of the follicular components of the ovary showed the shifts occurring during the estrual cycle both in number and in size of follicles (table 1).

TABLE 1. CHANGES IN THE PROPORTION OF FOLLICLES OF DIFFERENT SIZES DURING THE ESTRUAL CYCLES OF 33 FEMALES

Day of cycle	Percent follicles in class: Follicle size (mm) >5	5–7	8–10	<10	Cysts	Aver. no. follicles in both ovaries	Gonadotrophic hormone in pituitary[1]	Stage in cycle
4	100.0					13	14.7	Luteal phase
5		100.0				19	13.5	
6	56.2	39.7			4.1	24	17.2	
7	47.4	52.6				19	14.1	
8	74.5	25.5				49	23.5	
9		88.8			11.1	49	29.6	
10	61.5	38.5				42	26.1	
13	67.9	30.1			2.0	51	28.1	
14	51.4	46.0	2.7			37	22.5	Follicular phase
16	39.5	59.3	1.2			40	23.1	
17	47.2	51.7	1.1			45	26.4	
18	56.4	33.3	10.3			39	33.5	
19	43.9	8.7	47.4			57	20.5	
20	83.9	16.1				62	22.5	
1	5.1	8.9	76.0	8.9	1.3	16	13.7	Heat
2	—	—	69.2	30.8	—	13	17.1	Heat

[1] Testes weight, mgs.

In an attempt to avoid the difficulty mentioned above the approximate area of the surface of the ovary that was occupied by macroscopically visible follicles was determined by multiplying the number of follicles by their diameter. The figure thus obtained was designated as the "follicle index." The sum of the follicle indices of both ovaries of an animal was used in subsequent statistical analyses. The same calculations were made using the uncorrected follicle count and the follicle index and the two showed sufficiently close agreement to justify the use of the latter.

Results and Discussion

Thirty-three normally cycling sows were killed at certain intervals during the estrual cycle and their pituitaries assayed for gonadotrophic and thyrotrophic hormones.

During the first third of the estrual (days-1 through -7) the gonadotrophic potency was low and the number of follicles and the follicle index was also low (tables 1 and 2, figure 1). It should be

TABLE 2. CHANGES IN THE HORMONE CONTENT OF PITUITARIES FROM SOWS AND GILTS DURING THE ESTRUAL CYCLE

Donors						Assay Animals (chicks)			
						Average weights (mgs.)			
Day of cycle	Number of donors	Average Follicle Index	Average Number corpora lutea	Pituitary weight (gms) Sows	Pituitary weight (gms) Gilts	Testes Sows	Testes Gilts	Thyroids Sows	Thyroids Gilts
1	5	141	6.2	.39	.21	15.5	10.9	7.6	4.6
2	3	149	10.3	.57	.22	19.8	15.9	10.1	4.9
4	1	65	15.0	—	.19	—	14.7	—	4.3
5	2	51	14.5	.34	.12	14.5	12.5	7.6	4.1
6	3	136	16.6	.56	—	17.2	—	6.5	—
7	1	123	18.0	.67	—	14.1	—	5.5	—
8	2	250	15.5	—	.21	—	23.5	—	6.9
9	1	157	14.0	.43	—	29.0	—	8.0	—
10	2	236	14.5	.47	.21	25.2	27.0	8.6	6.1
13	3	287	14.0	.49	—	28.2	—	6.8	—
14	2	216	13.0	.30	—	22.5	—	8.6	—
16	2	230	11.0	.50	.18	25.4	20.8	7.3	7.6
17	2	272	12.0	.46	—	26.4	—	7.3	—
18	1	240	12.0	—	.22	—	33.5	—	7.8
19	2	200	12.5	.34	—	20.5	—	9.5	—
20	1	322	6.0	—	.21	—	22.5	—	7.3
Total or Average	33	184	12.2	.45[1]	.20[1]	19.3	21.4	7.7[1]	5.8[1]
Controls						9.3		3.8	

[1] Differences significant p=0.01.

noted that this period includes days-1 and -2 of the cycle during which all of the eight females killed on these two days were in heat. One of the females killed on day-2 had ovulated and all the females past day-2 had ovulated at autopsy. The low gonadotrophic potency of the pituitaries from females in heat may be due to the inhibition of the pituitary by follicular estrogen during heat, and is primarily due to a shift in the proportion of FSH and LH.

On day-8 the gonadotrophic hormone titer suddenly increased and remained high during the remainder of the cycle. This abrupt increase

was accompanied by an abrupt increase in the follicle numbers found in the ovaries (tables 1 and 2, figure 1). The follicle index and follicle number reached peaks on days-13 and -20. One might be justified in explaining these two peaks and the trough between them on the basis of insufficient numbers of animals involved in this study. However, in an independent companion study in this laboratory by Green (1950) in which 58 females were used, a remarkably similar curve was obtained also showing peaks of maximum follicle numbers on days-13 and -20 separated by a trough.

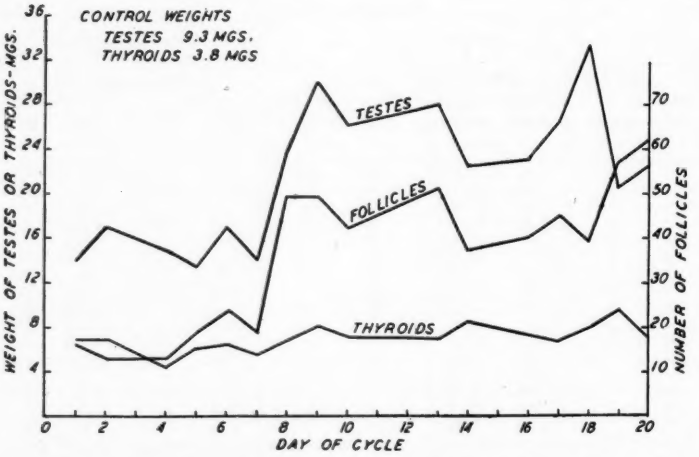


Figure 1. Simultaneous changes in the gonadotrophic hormone of the pituitaries and the follicle number in the ovaries of female swine during the estrual cycle. Animals were in heat on days-1 and -2. Ovulation occurred on days-2 or -3.

Of interest are the shifts in the proportion of follicles of various sizes occurring during the estrual cycle (table 1).

Coinciding with the increasing secretion of gonadotrophic hormone on day-8, there is an increase in the number, but not in the size of the follicles. The beginning of the follicular phase as judged by uterine histology (Green 1950) is the result of the increase in follicle size which does not begin until day-14 of the cycle (table 1). Major changes in follicular size continue until the second day of heat. From the 20th day to the 1st day of heat there is also a very pronounced drop in the number of follicles from about 60 to the ovulatory number which

coincides with the pronounced decrease in the gonadotrophic hormone content of the pituitary. The reduction of the follicle number is due to degeneration (Green 1950) and is undoubtedly caused by the decrease in the amount of FSH secreted by the hypophysis.

While the presence of follicles classified as "cysts" (table 1) and appearing during the luteal phase will be discussed in more detail in another paper (Green and Nalbandov, unpublished), a brief explanation appears necessary. One or two such cysts, measuring up to 30 mm. in diameter, are frequently found during the luteal phase in swine. They do not affect the reproductive performance and are "retained" follicles which have failed to ovulate after the last previous heat. They degenerate before the next heat.

According to the Moore-Price law one would expect a close correlation between the gonadotrophic hormone content of the pituitary and the events in the ovaries. But in spite of the fact that many pituitary assays have been and are being reported in the literature, the question has never been answered what is actually being measured in these assays. Three alternatives are possible: (1) that the actual rate at which gonadotrophic hormones are being secreted is determined in the assay, (2) that the secretory rate in the gland does not change and that the amount of hormone found in the gland reflects only the quantity stored, and (3) that the hormone enters into circulation as fast as it is being produced and that therefore the assay reveals only the residual amounts of gonadotrophin in the gland. If either of the last two alternatives are correct then the information that one obtains from bio-assays loses most of its value.

It is evident that it is theoretically and practically important to know with which of these three possibilities one is dealing when bio-assays of the pituitary gland are undertaken. As far as the authors are aware, no one has attempted to correlate the gonadotrophic potency of the pituitary as revealed by test animals with the ovarian picture of donors with long estrual cycles.

From the data presented it seems justifiable to propose that we are not only measuring the gonadotrophic potency of the pituitary at the time of the animal's death but that we are also measuring its rate of secretion (tables 1 and 2, figure 1). This assertion is based on the fact that changes in the number of follicles in the ovaries closely follow changes in the gonadotrophic potency of the pituitary.

In order to determine the degree of association between the various factors in which we were interested a number of correlation coefficients

were calculated (figure 2). The correlations between the gonadotrophic hormone, the follicle index, and the day in the cycle were high and statistically significant (p=0.01) and indicated that the former two were mutually interdependent and that both of them increased with the progressing estrual cycle. These figures further support the con-

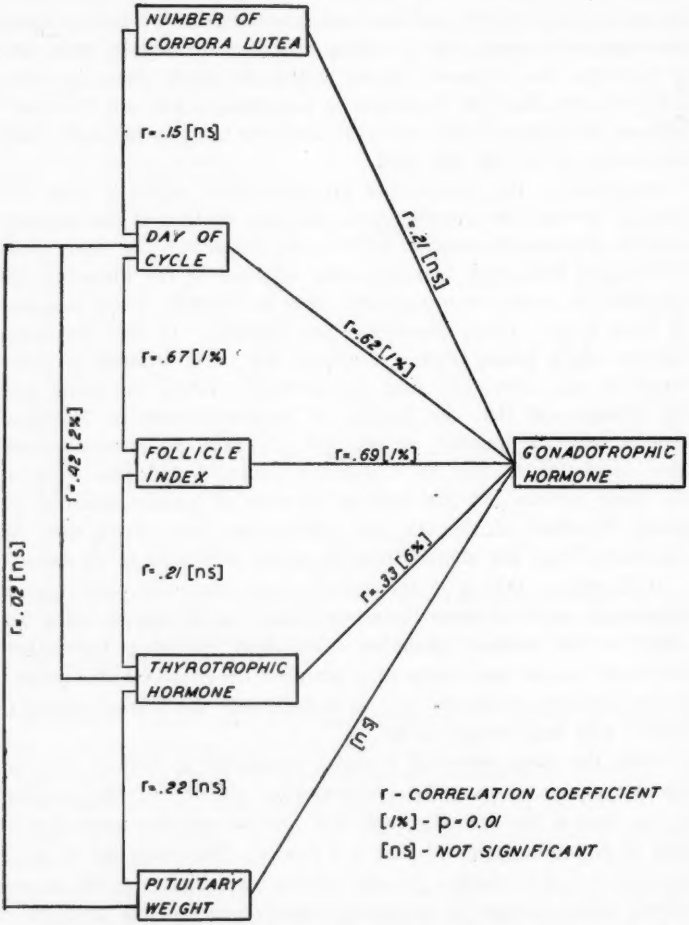


Figure 2. Correlation coefficients between the various factors studied.

clusion that as far as the gonadotrophic hormone is concerned the potency of the pituitary accurately reflects the rate of secretion of that hormone by the hypophysis.

There was no change in the weight of the pituitary during the estrual cycle and no correlation between its weight and its gonadotrophic or thyrotrophic hormone content.

It is commonly assumed that the prolificacy of polytocous animals is genetically controlled. It is of interest to note in this connection, that there was no significant correlation between the gonadotrophic potency and the number of corpora lutea. This may be due to the fact that the number of corpora lutea found is the result of the amount of hormone secreted in the previous cycle and thus the result of the number of follicles matured and ovulated then. In this study we were not measuring differences in the gonadotrophic hormone output between genetically different strains, but were only concerned with changes occurring during the estrual cycle. That genetically different strains do produce significantly different amounts of gonadotrophic hormone has been demonstrated in another phase of this study (Robinson and Nalbandov, unpublished).

The amount of thyrotrophic hormone secreted also increases during the cycle ($r=0.45$, $p=0.05$) but it does not appear to be associated with ovarian activity ($r=0.21$, ns.) or the gonadotrophic potency of the pituitary ($r=0.33$, $p=0.06$).

Summary

Assay of individual pituitaries from 33 female swine killed on almost every day of the 21-day estrual cycle showed that the gonadotrophic hormone was lowest during the two days of heat, remained low after ovulation until the eighth day of the cycle when it increased suddenly and remained high until the 20th day.

There is complete correspondence between the rise or fall in gonadotrophic hormone in the pituitary and the rise or fall in the number but not the size of follicles. The follicular phase, as judged by uterine histology, begins on the 14th day of the cycle which coincides with the increase in follicle size and is independent of the increase in follicle number.

A very high positive association was found between the day of the cycle and the gonadotrophic potency ($r=0.62$, $p=0.01$) and between the gonadotrophic potency and the number and size of follicles in the ovaries ($r=0.69$, $p=0.01$).

These correlations and other considerations lead to the conclusion that so far as the gonadotrophic hormone is concerned the bio-assay of the pituitary actually reflects the rate at which this hormone is being secreted.

There is an increase in the amount of thyrotrophic hormone secreted during the cycle ($r=0.42$, $p=0.02$), a questionable association between this hormone and the rate of secretion of gonadotrophic hormone ($r=0.33$, $p=0.06$) and no association between the thyrotrophic hormone and the events in the ovaries ($r=0.21$, ns.).

There is no change in the weight of the pituitary during the cycle and no association between its weights and the rate of hormone secretion.

Literature Cited

Faermark, S. E. and L. S. Singerman. 1938. Gonadotropic activity of pituitary at various stages of sexual cycle and pregnancy. Bul. Biol. Med. Exp. URSS 6:89.

Green, J. A. 1950. Studies on the histology of the female reproductive system of the domestic pig. Ph.D. Thesis Univ. of Ill., Urbana.

Wilson, R. F., A. V. Nalbandov and J. L. Krider. 1949. A study of impaired fertility of female swine. JOURNAL OF ANIMAL SCIENCE 8:558.

Wolfe, J. M. 1931. Observations on a cyclic variation in the capacity of the hypophysis to induce ovulation in the rabbit. Am. Jour. Anat. 48:391.

VARIATION IN PUBERTY PHENOMENA IN INBRED GILTS[1]

A. C. WARNICK, E. L. WIGGINS, L. E. CASIDA,
R. H. GRUMMER and A. B. CHAPMAN
University of Wisconsin[2]

A LARGE proportion of the pigs produced each year is farrowed by gilts. In spite of this, very little information is available on puberty phenomena in swine.

The factors influencing age at puberty probably have been studied more extensively in the rat than in any other mammal. Hereditary differences in age at vaginal opening in different strains of rats have been found by Blunn (1939) and by Bass (unpublished data, University of Wisconsin). Both workers also found that faster growing rats tended to reach puberty earlier than slower growing ones. Engle, Crafts and Zeithmal (1937) reported that female rats from small litters reached puberty earlier than animals from large litters principally because of differences in growth rate. Asdell and Crowell (1935) reported that age at vaginal opening in young rats could be delayed by limiting the caloric intake of their diet.

In swine, Phillips and Zeller (1943) reported differences in age at puberty between large and small type Poland China gilts, the average ages being 208 and 199 days respectively.

Wiggins, Casida and Grummer (1950) reported highly significant differences in the proportion of market gilts of similar weight having immature reproductive organs in the different seasons of the year and also found significantly fewer juvenile animals in a group of gilts born late in the spring than in a group born early in the spring although the latter group was slightly older at the time of slaughter. McKenzie (1928) reported that a low plane of nutrition retarded the growth of the genital organs in gilts.

Stewart (1945) has reported that gilts farrowing at 320 days averaged 1 pig less per litter and those farrowing at 410 days one-half pig more than those farrowing at one year of age. Other workers have established that sows farrow more pigs than gilts (Vestal, 1936; Russell and Hutton, 1938; Lush and Molln, 1942; Stewart, 1945). Squires *et al.* (1949) reported that the ovulation rate was higher

[1] Paper No. 439 from the Department of Genetics, University of Wisconsin.
[2] With the cooperation of the Regional Swine Breeding Laboratory, U.S.D.A.

in sows than in gilts. The relative importance of a higher ovulation rate, a higher fertilization rate or a lower embryonic death rate in the age-increase in litter size is not known.

The present study is an attempt to identify some of the causes of variation in age at puberty, ovulation rate, fertilization rate and number of pigs farrowed by gilts of different inbred lines.

Materials and Methods

The animals in this study were from the inbred herd of swine maintained by the Wisconsin Agricultural Experiment Station in cooperation with the U.S.D.A. Regional Swine Breeding Laboratory. They consisted of 3 inbred Chester White lines (MA, AK and PM), 1 inbred Yorkshire line (York.) and 1 inbred line originating from a cross between Chester White and Yorkshire (CY). The average of the inbreeding coefficients of the different lines was 0.27 in 1948 and 0.29 in 1949.

All gilts were checked daily with a vasectomized boar beginning on September 9, in 1948 and July 11, in 1949. The greatest age of any gilt on these respective dates was 189 and 133 days. Only 3 gilts came into heat within 23 days after the beginning of the daily heat checks in 1948 and none came into heat within 23 days in 1949 so it is believed that few, if any, estrual periods were missed before the daily heat checks began.

Gilts retained in the breeding herd were bred during the regular breeding season (November 10 to December 30 in 1948 and November 10 to January 1 in 1949) and furnished information on percentage of animals conceiving at first breeding (conception rate) and on litter size at farrowing (farrowing rate). Gilts not selected for breeding were moved to the laboratory and slaughtered at planned intervals after puberty to obtain information on ovulation and fertilization rates.

Results and Discussion

Age and Weight at Puberty in Relation to Year and Line of Breeding

The average ages at puberty were 236 days in 1948 and 251 days in 1949 (table 1). The corresponding average weights at puberty were 176 and 201 pounds. In 1948 the range in age at puberty in those animals actually coming into heat was 176 to 300 days and in addition 1 gilt had not been in heat when slaughtered at 327 days of age.

TABLE 1. AVERAGE AGES AND WEIGHTS AT PUBERTY IN FIVE LINES OF INBRED GILTS

Line	Number of Animals		Average Inbreeding Coefficients		Average 154 day Weight		Average age at puberty (days)		Average weight at puberty (pounds)	
	1948	1949	1948	1949	1948	1949	1948	1949	1948	1949
AK	25	9	.26	.24	98	98	245±6.5	270±17.0	200±8.0	236±11.7
MA	17	19	.29	.33	83	99	236±6.3	270± 8.1	178±6.8	225± 9.7
PM	31	17	.23	.39	90	84	228±4.2	236± 7.7	165±6.0	187± 7.7
York	23	14	.25	.21	88	72	243±4.9	249±13.8	165±5.5	180± 7.3
CY	18	32	.30	.30	91	93	226±6.3	231± 6.4	171±6.0	180± 4.6
Total or Unweighted Mean	114	91	.27	.29	90	89	236	251	176	201

Similarly in 1949 the range was 163 to 306 days and 13 animals had not reached puberty when slaughtered at 335 days. For analysis these gilts that were slaughtered before coming into heat were considered to have reached puberty on the day of slaughter, i.e. at 327 or 335 days. Thus the average ages and weights at puberty and the variation in age and weight at puberty were somewhat less than they would have been had it been possible to wait for every animal to come into heat.

Line and year differences in both age and weight at puberty were highly significant and the line x year interaction was significant for weight at puberty but not for age at puberty (table 2). There were

TABLE 2. ANALYSIS OF VARIANCE IN AGE AND WEIGHT AT PUBERTY

Source of Variation	d/f	Mean Squares For Age at puberty	Mean Squares For Weight at puberty
Years	1	13393**	35988**
Lines	4	6060.1**	12730**
Years x Lines	4	1586	2215*
Error	195	954	663

* $P \geqq 0.05$.
** $P \geqq 0.01$.

several outbreaks of scours in this herd in both years and mortality was very high. Since there were differences in the average farrowing dates among the lines it is probable that some lines were more severely affected than others. This in turn could have brought about line differences in state of health, rate of growth, etc. which could result in line differences in age and weight at puberty. It appears, however, that genetic differences among the lines were the major causes of line differences in age at puberty. There was a pronounced tendency for the same lines to reach puberty either early or late in both years although there was a significant year-difference in age at puberty. Environmental factors affecting the lines in a differential way could cause line differences in age at puberty in either year or in both years but it seems unlikely that the same lines would be affected in exactly the same way in two consecutive years. As a matter of fact the significant year x line interaction for weight at puberty indicates that environment did not affect the same lines in the same way each year.

Age at Puberty in Relation to Weight at Different Ages

In 1948 only 56 and 154 day weights were available for use in studying the relation of body weight at various pre-puberal stages to the age at puberty. The correlation between weight at 56 days and the age at puberty was negative in all lines and significant in 3 of the five lines (table 3). Since the sizes of the correlations were not significantly different in the five lines (Snedecor, 1946) the data were pooled to yield a correlation of —0.54. The corresponding regres-

TABLE 3. ASSOCIATION OF 56 AND 154 DAY WEIGHTS WITH AGE AT PUBERTY IN 1948 GILTS AND REGRESSION OF AGE AT PUBERTY ON WEIGHT AT THOSE AGES

Line	Number of Animals	56 days		154 days	
		r	b	r	b
AK	25	—.73**	—3.72	—.65**	—.71
MA	15[1]	—.64*	—3.10	—.72**	—.73
PM	31	—.43*	—1.86	—.48**	—.43
York	23	—.34	—2.20	—.57**	—.85
CY	18	—.39	—2.46	—.48*	—.70
X^2 (Lines)		5.28		1.88	
Pooled r or b		—.54**	—2.8	—.58**	—.64

* $P \leqq 0.05$.
** $P \leqq 0.01$.
[1] Weights not available on two animals in this line.

sion coefficient was —2.8, i.e. there was a reduction of 2.8 days in age on the average at puberty for each one-pound increase in 56 day weight. The correlation between 154 day weight and age at puberty was negative and significant in all lines. The pooled correlation coefficient was —0.58 and the regression was —0.6.

In 1949 all animals were weighed at 56 days and then at 2 week intervals from 98 to 168 days. It was thought that weight at some ages might be more highly correlated with age at puberty than weight at other ages and also that the correlation might be higher in some lines than in others. Thus indirect selection for early sexual maturity on the basis of body weight might be more effective at one age than another and also might be more effective in some lines than in others. The correlations between body weight and age at puberty were nega-

tive in all lines at all ages (table 4). They were highly significant at all ages in 3 lines and at some ages in another line. In the remaining line, which consisted of only 9 animals, none of the correlations were significant although they averaged about —0.4. The correlations at different ages within lines were not heterogeneous, i.e. age at puberty was no more highly associated with weight at one age between 98 and 168 days than it was with weight at another. At one age (140 days) the sizes of the correlations were significantly different in the 5 lines.

In contrast to the significant, negative within-line correlation between 154 day weight and age at puberty, the between-line correlation was

TABLE 4. CORRELATION BETWEEN WEIGHT AT DIFFERENT AGES AND AGE AT PUBERTY IN 1949 GILTS

Age (days)	Line and Number of Animals					X^2	Pooled
	AK (9)	MA (19)	PM (17)	York (14)	CY (32)	(Lines)	r
98	—.45	—.72**	—.43	—.77**	—.67**	3.22	—.62**
112	—.40	—.73**	—.47	—.81**	—.69**	3.54	—.64**
126	—.29	—.71**	—.50*	—.86**	—.70**	5.36	—.64**
140	—.27	—.84**	—.47	—.97**	—.69**	19.15**	..
154	—.38	—.72**	—.57*	—.87**	—.66**	4.53	—.66**
168	—.44	—.69**	—.56*	—.88**	—.70**	4.60	—.68**
X^2 (ages)	0.22	1.44	0.41	6.18	0.18		

* Significant ($P \geqq 0.05$).
** Highly significant ($P \geqq 0.01$).

significantly positive in both years (pooled r=0.45). The within-line and between-line correlations were significantly different. Thus within the lines the heavier animals at 154 days tended to reach puberty before the slower growing animals in the same line but the lines having the heaviest average 154 day weights tended to be the slowest to reach puberty. It is possible that the same genes that acted to bring about rapid growth tended to retard sexual development causing the rapid growing lines to reach puberty at older ages; but within lines, disease and other factors masked the positive genetic correlation between 154 day weight and age at puberty and caused the observed correlation to be negative.

Age at Puberty in Relation to Rate of Gain

In general the simple correlations between rate of gain and age at puberty were lower than those between body weight and age at puberty but in all but one line, one or more of the correlations was significant (table 5). Again there was no heterogeneity of the correlations over all

TABLE 5. CORRELATION BETWEEN GAINS IN BODY WEIGHT DURING DIFFERENT 14 DAY INTERVALS BEFORE PUBERTY AND AGE AT PUBERTY IN 1949 GILTS

Interval (days of age)	Line and Number of Animals					X^2	Pooled
	AK (9)	MA (19)	PM (17)	York (14)	CY (32)	(Lines)	r
98–111	−.18	−.61**	−.43	−.73**	−.52**	3.08	−.51**
112–125	−.07	−.34	−.47	−.89**	−.60**	10.24*	...
126–139	−.05	−.42	−.14	−.49	−.48**	2.31	−.34**
140–153	−.15	−.26	−.58*	−.51	−.35*	1.92	−.42**
154–167	−.49	−.02	−.24	−.84**	−.52**	10.44*	
X^2 (Ages)	1.05	4.09	2.45	6.76	1.70		

* Significant P≧0.05.
** Highly Significant P≧0.01.

ages within lines but the sizes of the correlations in the different lines were significantly different at 2 stages indicating that rate of gain may be more indicative of age at puberty in some lines than in others.

Multiple correlations of body weight and rate of growth with age at puberty were very similar to the simple correlation between weight and age at puberty, both in magnitude and in significance (table 6). At 3 stages, however, the sizes of the correlations in the different lines were significantly different while in the simple correlations of weight and age at puberty the differences were significant at only one stage.

Effect of Stage of Season When Farrowed on Age at Puberty

Simple correlation coefficients between stage of farrowing season (number of days from March 1 to farrowing) and age at puberty were computed for each line each year. In 1948 the correlations were negative in all lines and significant in two lines (table 7). The sizes

TABLE 6. MULTIPLE CORRELATIONS OF WEIGHT AT DIFFERENT AGES AND GAINS IN WEIGHT DURING THE SUBSEQUENT 14 DAYS WITH AGE AT PUBERTY

Age (days)	Line and Number of Animals					X^2 (lines)
	AK (9)	MA (19)	PM (17)	York (14)	CY (32)	
98	.46	.73**	.48	.80**	.72**	3.22
112	.44	.73**	.52	.98**	.70**	23.93**
126	.30	.72**	.55	.90**	.70**	6.61
140	.27	.86**	.73**	.97**	.71**	15.70**
154	.51	.73**	.57	.89**	.73**	11.69**
X^2 (Ages)	0.22	1.81	1.42	10.64*	0.12	

* Significant P≧0.05.
** Highly SignificantP≧0.01.

TABLE 7. CORRELATION BETWEEN FARROWING DATE AND AGE AT PUBERTY IN GILTS

Line	Number of Animals		Number of Days After March 1 to Farrowing: Range		Average		Correlation Between Farrowing Date and Age at Puberty	
	1948	1949	1948	1949	1948	1949	1948	1949
AK	25	9	6–48	7–40	30.0	20.9	−.46*	−.12
MA	17	19	30–57	1–49	39.2	23.2	−.46	+.56*
PM	31	17	4–64	8–51	30.9	20.8	−.45*	−.30
York	23	14	4–38	5–54	19.7	29.1	−.03	−.0004
CY	18	32	6–41	4–42	24.3	13.4	−.04	+.17
X^2 (Lines)	..	..	..	..	..	..	4.79	9.13
Pooled r	..	..	..	..	..	..	−.27**	+.12

* $P \geqq 0.05$.
** $P \geqq 0.01$.

of the correlations were not significantly different and the pooled correlation was −0.27. In 1949 the correlations were negative in three lines and positive in two lines. The pooled correlation was +0.12. A negative correlation between season of farrow and age at puberty in outbred gilts was reported in a previous paper (Wiggins, Casida and Grummer, 1950) and this was also found by Robertson, Casida and Grummer (unpublished) in outbred gilts at this station. The 1948 data agree with these findings but there are exceptions in the 1949 data. In view of the importance of body weight in determining age at puberty it seems possible that the disease mentioned earlier either acted directly or affected body weight in such a way as to mask the effect of season of birth which would ordinarily be expressed.

Age at Puberty of Gilts by Different Sires

There were only two lines in which two sires were represented by two or more litters containing more than one gilt per litter. In one of these lines the difference in age at puberty of gilts by different sires was significant but in the other line the difference was not significant (table 8).

TABLE 8. ANALYSIS OF VARIANCE OF AGE AT PUBERTY IN TWO LINES OF INBRED GILTS

Source of Variation	MA		CY	
	d/f	Mean Square	d/f	Mean Square
Between sires	1	11969*	1	1723
Between litters Within sires	3	1013*	6	828
Between pigs Within litters	13	378	21	1619

* Significant $P \geqq 0.05$.

TABLE 9. OVULATION RATES AT THE FIRST AND SECOND HEAT PERIODS IN THE SAME ANIMALS

Line	Number of Animals	Ovulation Rate at: First heat	Second heat	Difference (2nd—1st)
AK	10	11.8	12.7	+0.9
MA	2	7.0	9.0	+2.0
PM	9	11.8	12.2	+0.4
York	10	8.5	10.0	+1.5
CY	17	11.0	10.3	—0.7
Total or Unweighted Mean	48	10.0	10.8	+0.8

r, age at puberty and ovulation rate=—.243.
b, ovulation rate on age at puberty=—.021.

Ovulation Rates at Different Heat Periods

Most of the animals that furnished information on ovulation and fertilization rates were slaughtered after the second heat and since the corpora albicantia from the first ovulation could be identified it was possible to obtain information on ovulation rates at the first and second heat periods in the same animal. In the remainder of the animals information on ovulation rate at only one heat period could be obtained. In those animals slaughtered after the second heat period there was an average increase of 0.8 eggs from the first to second ovulation but there was considerable line-to-line variation (table 9). Line differences in ovulation rate at first heat were highly significant. There was a correlation of —0.24 (which approached significance) between ovulation rate at first heat and age at puberty and an increase of 0.02 eggs ovulated with each one-day decrease in age at puberty.

While the number of observations was extremely small at the third and later heat periods there appeared to be a gradual although statistically insignificant increase in ovulation rate at each succeeding heat period through the third (table 10).

TABLE 10. OVULATION RATES IN GILTS SLAUGHTERED AT DIFFERENT HEAT PERIODS

Heat period	Number of Animals	Average number of corpora lutea
First	48	10.0
Second	48	10.8
Third	7	11.9
Fourth to Seventh	4	12.0

Effect of Sexual Age of Gilts at Conception on the Number of Pigs Farrowed

It is the policy in this herd to restrict the fall breeding season to a period of about 6 weeks and as a consequence some of the later maturing gilts had to be bred at their puberal heat while others had several heat periods before being bred. Gilts conceiving at the third and later heat periods farrowed an average of 1.4 pigs per litter more than those conceiving at second heat and 2.5 pigs more than those conceiving at first heat (table 11). It should be pointed out

TABLE 11. EFFECT OF ORDER NUMBER OF HEAT PERIOD AT CONCEPTION ON SIZE OF LITTERS FARROWED BY GILTS

Line	Heat at Conception						Total	
	First		Second		Third to Fifth			
	Number of Litters	Average Litter Size	Number of Litters	Average Litter Size	Number of Litters	Average Litter Size	Number of Litters	Average Litter Size
AK	7	7.7	4	9.0	2	10.0	13	8.5
MA	7	8.1	2	6.5	4	10.8	13	8.5
PM	2	5.5	9	7.7	1	9.0	12	7.4
York	7	7.1	3	8.7	2	9.5	12	8.4
CY	1	6.0	4	8.2	10	7.5	15	7.2
Total or Unweighted Mean	24	6.9	22	8.0	19	9.4	65	8.0

however that gilts bred at different heat periods were not the same age at puberty and differences in farrowing rates could be due at least in part to factors other than differences in sexual age at conception. The differences in the number of pigs farrowed by gilts of different lines or different sexual ages at the time of conception were not significant although the latter approached significance.

Conception Rates in Gilts Bred at Different Heat Periods

The percentages of gilts conceiving on first service (virgin matings) at different heat periods were computed. The conception rate was lowest in gilts bred at the third heat (55%) and highest in gilts bred for the first time at the second heat period (80%) (table 12). The differences in conception rate at the different heat periods were not significant with these numbers.

Fertilization Rates

The animals which furnished information on fertilization rates were checked for heat once daily and were bred (natural service)

TABLE 12. CONCEPTION RATES IN GILTS BRED FOR THE FIRST TIME AT DIFFERENT HEAT PERIODS

Heat period	Number of Gilts bred	Percent Conceiving
First	56	58.9
Second	20	80.0
Third	20	55.0
Fourth and Fifth	9	77.8
Total or Unweighted Mean	105	67.9
X^2 (heat periods)	—	4.28

as soon as they were found in heat, i.e. within the first 24 hours of estrus. The average fertilization rate was 82% in the 63 animals studied. Only 3.2% of the animals had no fertilized eggs and 49.2% had all eggs fertilized (table 13). The fertilization rate was 75% in about three-fourths of the animals and 50% or higher in 87%. Since almost 97% of the animals had some fertilized eggs it would appear that breeding early in the heat period would not have an adverse effect on conception rate in gilts. However, Weaver and Bogart (1943) did report that the conception rate as well as litter size was higher in gilts bred twice during the heat period than in those bred once.

Discussion

The average age at puberty for the 205 inbred gilts of Chester White and Yorkshire ancestry in a two year period was about 8

TABLE 13. FERTILITY OF GILTS BRED WITHIN 24 HOURS AFTER THE ONSET OF ESTRUS

Percent of Fertility Shown	Number of Gilts	Percent of All Gilts	Cumulative Percentage
100	31	49.2	49.2
75–99	17	27.0	76.2
50–74	7	11.0	87.2
25–49	3	4.8	92.0
1–24	3	4.8	96.8
0	2	3.2	100.0
Total	63	100.0	100.0

months. For comparison outbred Poland China gilts at Beltsville (Phillips and Zeller, 1943) and outbred Poland China and Chester White gilts at this station (Robertson *et al.*, unpublished data, University of Wisconsin) reached puberty at average ages of slightly less than 7 months. However, the gilts in this study had average inbreeding coefficients of more than 25 percent and showed marked variability in thriftiness and general health which could account for their being later maturing.

The important effect of body weight and rate of growth on age at puberty within lines is shown by the high correlations of these factors with age at puberty at all ages between 56 and 168 days, although there is a suggestion that they may not be of equal importance in all lines. In contrast, correlations between weight and age at puberty or rate of gain and age at puberty were much lower and insignificant as most stages in outbred gilts which were in a more thrifty condition (Robertson *et al.*, unpublished). Thus it appears that body weight and rate of growth have an important effect on age at puberty in gilts only in cases where there is considerable variation in health and thriftiness. Even though there was a decided tendency for the heavier, faster growing gilts to reach puberty sooner than slower growing gilts in the same lines, the lines having the heaviest average 154 day weights tended to be the slowest lines to reach puberty. Thus it would appear that the genes that bring about rapid growth also tend to retard sexual development but that disease and other environmental factors can destroy this correlation within lines. The negative correlation between stage of farrowing season and age at puberty in the 1948 data agrees with the findings reported by Wiggins *et al.* (1950). However in 1949 some of the correlations were positive. It may be that in these lines other factors which probably affected weight and rate of gain masked the effect of stage. In support of this is the fact that in the outbred herd (Robertson *et al.*, unpublished) where weight and gain did not have an important relation to age at puberty the correlation between stage of farrowing season and age at puberty was negative and highly significant in both breeds.

The increase in ovulation rate at the second heat agrees with the findings of Robertson *et al.* (unpublished) in outbred gilts. In these data there was an indication that the earlier maturing gilts tended to have a higher initial ovulation rate while in the outbred herd the correlation between age at puberty and ovulation rate was extremely low in both Chester White and Poland China breeds. Thus it may be that the factors (environmental) which tend to delay puberty may also

depress the initial ovulation rate. The significant line differences in ovulation rate are in agreement with the findings of Squires *et al.* (1949) who found significant line differences in ovulation rate in both gilts and sows. The line differences in farrowing rates in this study were not significant but it is pointed out that the number of gilts per line was relatively small and real differences may have existed which escaped detection because of small numbers.

The average ovulation rate was 10.0 eggs at first heat and 10.8 eggs at second heat and the average fertilization rate in gilts bred at the second and later heats was 82%. If the ovulation and fertilization rates were assumed to be the same in the sisters of these gilts which were saved for breeding the expected litter sizes in gilts conceiving at first and second heats would be 8.0 and 8.6 pigs per litter. However the actual litter sizes were 6.9 and 8.0. The discrepancy between actual and expected litter sizes in gilts bred at first heat could be due either to embryonic death or to a lower fertilization rate inasmuch as no measure of fertilization rate for first heat is available. In gilts bred at the second heat the discrepancy would appear to be due mainly to embryonic death. This is in agreement with the findings of Squires *et al.* (1949).

Although only 74% of the gilts retained in the breeding herd appeared to conceive at first service almost 97% of the gilts slaughtered after heat had some fertilized eggs. This would seem to indicate that complete lack of fertilization is only a minor cause of repeat-breeding in gilts, excluding of course those animals in which bilateral barriers in the genital tract make fertilization impossible. In studies of "repeat-breeder" gilts (older animals), Warnick, Grummer and Casida (1949) and Wilson, Nalbandov and Krider (1949) found that only about 4% of the reproductive failures in these animals were caused by unaccountable failures of fertilization, i.e. not due to bilateral barriers in the genital tract or failure of ovulation.

These data provide evidence that reproductive efficiency in gilts as measured by ovulation rate, conception rate and number of pigs farrowed increases with advancing sexual age at least through the third heat period. There is also a suggestion that initial ovulation rate is higher in the earlier maturing animals although this may be true only in herds where there is considerable variability in health and thriftiness of the animals. Therefore early sexual maturity would appear to be an important economic character that should receive attention from swine breeders both in the selection of breeding females and in providing the kind of an environment that tends to bring it about. Unfortunately

these data do not provide a good estimate of the heritability of age at puberty so it is impossible to estimate the progress to be expected from selection for early puberty. It is believed that such studies would be worthwhile and also that additional studies of environmental factors affecting age at puberty and other reproductive phenomena in gilts would be justified.

Summary

Data on age at puberty, ovulation rates at different heat periods, percentages of gilts conceiving at first breeding and litter size at farrowing were obtained on 205 inbred gilts of Chester White and Yorkshire ancestry in a two year period.

The average ages at puberty were 236 days in 1948 and 251 days in 1949. Corresponding average weights at puberty were 176 and 201 pounds. Line and year differences in both age and weight at puberty were highly significant but the line x year interaction was significant for weight at puberty only. The pronounced tendency for the same lines to be either early or late maturing in both years would appear to indicate that the line differences were due mainly to genetic differences of the lines. Within the lines body weights at all ages between 56 and 168 days were highly correlated negatively with age at puberty but the lines with the highest average 154 day weights tended to be the slowest to reach puberty. The correlations between rate of gain in successive two week intervals between 98 and 168 days were highly correlated negatively with age at puberty but the lines with the highest average 154 day weights tended to be the slowest to reach puberty. The correlations between rate of gain in successive two week intervals between 98 and 168 days and age at puberty were lower than those between body weight at the different ages and age at puberty. Multiple correlations of body weight and rate of gain at the different ages with age at puberty were very similar to the simple correlations between weight and age at puberty.

There was an average increase of 0.8 eggs in ovulation rate at second heat in 48 gilts in which the ovulation rates at both first and second heats could be determined. These data together with data on single ovulations in a limited number of animals slaughtered at other heat periods indicate a steady rise in ovulation rate at each succeeding heat period from first to fourth heat. Line differences in ovulation rate at first heat were highly significant.

Gilts conceiving at the third heat period farrowed an average of 1.4 pigs more than those conceiving at second heat and 2.5 more than those conceiving at first heat. These differences approached significance.

There was not a significant difference in the number of pigs farrowed by gilts of different lines.

Conception rates at different heat periods ranged from 55% to 80% but the differences were not significant.

The average fertilization rate in 63 gilts bred within 24 hours after the onset of estrus was 82%. Only 3.2% of the gilts had no fertilized eggs and 87% had 50% or more fertilized eggs indicating that a complete lack of fertilization is only a minor cause of repeat breeding in gilts. A comparison of the ovulation and fertilization rates in slaughtered gilts with the conception and farrowing rates of their sisters which were saved for breeding indicates that embryonic death is an important cause of "repeat-breeding" in gilts and also of the discrepancy between ovulation rate and litter size.

The data presented in this paper indicate that reproductive efficiency of gilts as measured by ovulation rate and fertilization rate increases with advancing sexual age.

Literature Cited

Asdell, S. A. and M. F. Crowell. 1935. The effect of retarded growth on the sexual development of rats. Jour. Nutr. 10:13.

Blunn, Cecil T. 1939. The age of rats at sexual maturity as influenced by their genetic constitution. Anat. Rec. 74:199.

Engle, E. T., R. C. Crafts and C. E. Zeithaml. 1937. First estrus in rats in relation to age, weight and length. Proc. Soc. Exp. Biol. and Med. 37:427.

Lush, J. L. and A. E. Molln. 1942. Litter size and weight as permanent characteristics of sows. U.S.D.A. Tech. Bul. 836.

McKenzie, F. F. 1928. Growth and reproduction in swine. Mo. Agr. Exp. Sta. Res. Bul. 118.

Phillips, R. W. and J. H. Zeller. 1943. Sexual development in small and large types of swine. Anat. Rec. 85:387.

Russell, E. Z. and R. E. Hutton. 1938. Comparative value of mature sows and gilts for producing market hogs. U.S.D.A. Cir. 472.

Snedecor, G. W. 1946. Statistical methods applied to experiments in agriculture and biology. 4th ed. The Iowa State College Press, Ames, Iowa.

Squires, C. D., E. R. Hauser, G. E. Dickerson and D. T. Mayer. 1949. Inbreeding and strain influences on components of fertility in sows. JOURNAL OF ANIMAL SCIENCE 8:644. (Abstract)

Stewart, H. A. 1945. An appraisal of factors affecting prolificacy in swine. JOURNAL OF ANIMAL SCIENCE 4:250.

Vestal, C. M. 1936. Feeding and management experiments with brood sows and litters. Ind. Agr. Exp. Sta. Bul. 413.

Warnick, A. C., R. H. Grummer and L. E. Casida. 1949. The nature of reproductive failures in repeat-breeder sows. JOURNAL OF ANIMAL SCIENCE 8:569.

Weaver, L. A. and Ralph Bogart. 1943. Some factors influencing efficient production of sows. Mo. Agr. Exp. Sta. Bul. 461.

Wiggins, E. L., L. E. Casida and R. H. Grummer. 1950. The effect of season of birth on sexual development in gilts. JOURNAL OF ANIMAL SCIENCE 9:277.

Wilson, R. F., A. V. Nalbandov and J. L. Krider. 1949. A study of impaired fertility in female swine. JOURNAL OF ANIMAL SCIENCE 9:558.

VARIATION IN PUBERTY PHENOMENA IN INBRED BOARS[1]

E. L. Wiggins, A. C. Warnick, R. H. Grummer, L. E. Casida and A. B. Chapman

University of Wisconsin[2]

HISTOLOGICAL studies of testes from developing boars have given information on the initiation of spermatogenesis but do not provide information on the age at which young boars develop the ability and desire to mate. Phillips and Andrews (1936) examined the testes of eight Chester White and Berkshire boars castrated at ages varying from 10 to 147 days of age. Little testicular development was noted before 84 days and sperm were found at 147 days. Phillips and Zeller (1943) studied the testes of 44 large type and 35 small type Poland China boars castrated at ages varying from 5 to 40 weeks. No sperm were found in the tubules of boars of either type before 20 weeks and in some individuals of both types no sperm were found at 20 or at 22.5 weeks. However sperm were found in some tubules in all animals of both types at 25 weeks or later. Boars of both types developed sperm at about the same average age but the small type was more variable in the time at which a major portion of tubules began producing sperm. There was some indication that the mature size of the tubules was greater in the large type and that the testes weight was greater in the large type at all ages above 25 weeks. More recently Andrews and Warwick (1949) studied the testes of more than 200 boars (outbreds, inbreds, crossbreds and linecrosses) castrated at ages varying from 70 to 140 days. In one strain sperm were found rather consistently at 110 days while in another strain sperm were not present in all individuals until 140 days; boars of other strains were intermediate between these two. In a similar study of 3 inbred lines and the crosses between them, Hauser, Squires, Dickerson and Mayer (1949) found that the crosses exceeded inbreds by 30 percent in body and testis weight and by 21 percent in epididymis weight and stage of spermatogenesis at an average age of 150 days.

From the above studies it appears fairly certain that sperm are present in the testes of most boars at about 5 months of age and there is an indication of breed and strain differences in rate of testicular

[1] Paper No. 436 from the Department of Genetics, University of Wisconsin.
[2] With the cooperation of the Regional Swine Breeding Laboratory, U.S.D.A.

development. However the presence of sperm in the testes does not necessarily mean that the individual will mate. Rice (1942) states young boars can be placed in light service at 8 or 9 months of age but apparently the age at which the average boar will mate is not known.

The present study was made to determine the age at puberty (first mating) in 5 lines of inbred boars and to study the effect of various factors on this phenomenon.

Materials and Methods

The animals used in this study were from the inbred herd maintained by the Wisconsin Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, U.S.D.A. They consisted of 3 lines of Chester Whites (AK, MA and PM), 1 line of inbred Yorkshires (York) and 1 line originating from a cross of Chester White and Yorkshire (CY). The average of the inbreeding coefficients of the different lines was 0.26 in 1948 and 0.27 in 1949. In 1948 about one-half of the pigs were castrated at weaning time and only the heavier, more thrifty pigs were saved for possible use as breeders. In 1949 no pigs were castrated and information was obtained on all pigs raised.

To check for the attainment of puberty a spayed "estrogenized" gilt (injected with an oil solution of an estrogen frequently enough to maintain estrus) was admitted to a pen with a small group of boars (usually 3–8). Boars were considered to have reached puberty when they began a mating within 15 minutes after the gilt was admitted to the pen.

Checking began on August 3, 1948 when the oldest pig was 172 days old and on July 8, 1949 when the oldest pig was 130 days old. Bi-weekly checks were made in 1948 and weekly checks were made in 1949. In both years the age at puberty was considered to be the mid-date between the last negative check and the first positive check except for 11 boars that were found to be puberal at the time of the first check in 1948 and 12 boars that had not reached puberty by 335 days of age in 1949. For analysis of the data the former were considered to have reached puberty on the day of the first check and the latter at 335 days; these considerations should have caused the average age at puberty to be somewhat high in 1948 and somewhat low in 1949 and the variation in age at puberty in both years to be less than it would have been had the age at puberty been ascertained more precisely in all animals.

Fertility tests were made on 15 animals in 1948 by means of artificial insemination. In 1949 fertility tests could not be made but semen was collected from a number of boars and examined for the presence of sperm.

Results and Discussion

The average ages at puberty were 196 days in 1948 and 205 days in 1949 (table 1). Corresponding average weights at puberty were 166 and 141 pounds. Line differences in age at puberty were significant in 1948 but not in 1949 and the "rank" of the lines with respect

TABLE 1. AVERAGE AGES AND WEIGHTS AT PUBERTY IN FIVE LINES OF INBRED BOARS

Line	Number of Animals		Average Inbreeding Coefficients		Average 154 Day Weight		Average Age at Puberty (days)		Average Weight At Puberty (Pounds)	
	1948	1949	1948	1949	1948	1949	1948	1949	1948	1949
AK	5	13	.18	.21	109	103	203	202	178[1]	145
MA	8	20	.33	.34	126	100	171	211	154	151
PM	11	21	.24	.35	115	94	186	189	176[2]	140
York	8	10	.25	.15	106	89	183	217	146	123
CY	9	31	.30	.30	113	96	196	206	178	148
Total or unweighted Mean	41	95	.26	.27	114	96	196	205	166	141

[1] Based on only 4 animals.
[2] Based on only 9 animals.

to age at puberty was not the same in the two years. However it should be borne in mind that the 1948 boars were a selected group and therefore the data for the two years are not comparable. Significant line differences in age at puberty were found in the gilts in this herd and the "rank" of the different lines of gilts was almost exactly the same in the two years (Warnick *et al.*, in press).

Age at Puberty in Relation to Weight at Different Ages

Only 56 and 154 day weights were available in 1948 to study the effect of weight at different ages on the age at puberty. The correlations between 56 day weight and age at puberty and between 154 day weight and age at puberty were insignificant in all lines (table 2). This could be a result of the culling of about one-half of the pigs at weaning time since elimination of the lighter pigs would reduce the variation in 56 day weight in the remaining pigs. Averages of standard

TABLE 2. ASSOCIATION OF WEIGHT AT 56 AND 154 DAYS WITH AGE AT PUBERTY IN BOARS AND REGRESSION OF AGE AT PUBERTY ON WEIGHT AT THOSE AGES

Line	Number of Animals		56 days				154 days			
			r		b		r		b	
	1948	1949	1948	1949	1948	1949	1948	1949	1948	1949
AK	5	13	+.29	−.58*	+13.1	−8.3	−.43	−.77**	−0.5	−1.9
MA	8	20	+.55	−.54*	+ 1.0	−5.3	+.42	−.73**	+0.2	−1.4
PM	11	21	−.26	−.31	− 0.7	−1.7	+.04	−.26	+0.04	−0.4
York	8	10	−.12	−.64*	− 0.4	−8.6	−.37	−.86**	−0.3	−2.2
CY	9	31	+.04	−.56**	+ 0.3	−5.2	−.02	−.72**	−0.04	−1.6

* $P \geqq 0.05$.
** $P \geqq 0.01$.

deviations of 56 day weights were 3.6 in 1948 and 6.1 pounds in 1949.

In 1949 the animals were weighed at 56 days and then at 14 day intervals from 98 to 168 days. In 4 lines the correlations between weight at 56 days and age at puberty were negative and significant or highly significant. Weights in these same 4 lines at all ages between 98 and 168 were highly significantly correlated with age at puberty (table 3). In the remaining line (PM) there was a significant correlation between 98 day weight and age at puberty but the correlation was not significant at 56 days or at any age subsequent to 98 days. There was no evidence of heterogeneity of the correlations at

TABLE 3. CORRELATION BETWEEN WEIGHT AT DIFFERENT AGES AND AGE AT PUBERTY IN 1949 BOARS

	Line and Number of Animals						
Age (days)	AK (13)	MA (20)	PM (21)	York (10)	CM (31)	X^2 (Lines)	Pooled r
98	−.69**	−.61**	−.62*	−.79**	−.64**	0.82	−.64**
112	−.82**	−.68**	−.41	−.83**	−.54**	5.93	−.70**
126	−.91**	−.71**	−.34	−.80**	−.72**	9.02	−.73**
140	−.83**	−.73**	−.30	−.84**	−.72**	7.47	−.69**
154	−.77**	−.73**	−.26	−.86**	−.72**	7.67	−.71**
168	−.62*	−.76**	−.22	−.90**	−.72**	10.14*	..
X^2 (Ages)	3.91	0.92	2.83	0.70	2.92		

* $P \geqq 0.05$.
** $P \geqq 0.01$.

different stages within the different lines, i.e. weight at one age was no more highly associated with age at puberty than weight at any other age between 98 and 168 days. The sizes of the correlations were significantly different in the different lines at 168 days but not at any other age.

The between-line correlation for 154 day weight with age at puberty was −0.22. This correlation is not significant but if anything it suggests that the lines having the highest 154 day weight tend to reach puberty first. In contrast, in the gilts in this herd the between line correlation was +0.45 suggesting that the lines having the higher 154 day weights tend to reach puberty later than the lines having the lighter 154 day weights (Warnick *et al.*, in press).

It has been the practice in this herd for a number of years to castrate about one-half of the pigs at weaning time and save for possible use as breeders only the better-appearing, more thrifty pigs

in the line. This practice was followed in 1948 but in 1949 the potential breeding boars were selected (by the same men) as before and the remainder of the boars marked for identification but not castrated. The "selected" boars weighed an average of 8 pounds more at weaning, 38 pounds more at 154 days and reached puberty 61 days earlier than those "not selected" for breeding (table 6). The difference in age at puberty between the "selected" and the "not selected" boars in the same line ranged from 7 to 136 days.

Age at Puberty in Relation to Rate of Gain

In the 1949 animals the correlations between rate of gain in successive 14 day intervals between 98 and 168 days and age at puberty were significant at all stages in 2 lines (MA and CY) and significant at some stages in 2 other lines (AK and York). In the remaining line (PM) rate of gain at any age was not significantly associated with age at puberty (table 4). With the exception of the AK line, the

TABLE 4. CORRELATION BETWEEN GAINS IN BODY WEIGHT DURING DIFFERENT 14 DAY INTERVALS BEFORE PUBERTY AND AGE AT PUBERTY IN 1949 BOARS

Interval (days of age)	Line and Number of Animals						
	AK (13)	MA (20)	PM (21)	York (10)	CY (31)	X^2 (Lines)	Pooled r
98–111	−.79**	−.71**	−.21	−.83**	−.73**	8.46	−.70**
112–125	−.81**	−.64**	−.08	−.61	−.74**	10.12*	..
126–139	−.46	−.69**	−.05	−.94**	−.52**	14.17**	..
140–153	−.12	−.60**	+.05	−.65*	−.50**	7.41	−.39**
154–167	+.12	−.49*	+.04	−.68*	−.41*	6.98	−.20
X^2 (Ages)	12.39*	1.00	1.34	4.26	5.90		

* $P \geqq 0.05$.
** $P \geqq 0.01$.

correlations within lines were not heterogeneous, i.e. age at puberty was no more highly associated with rate of gain at one time between 98 and 168 days than it was at another. The sizes of the correlations did vary significantly between different lines at 2 stages, 112 to 125 and 126 to 139 days.

Multiple correlations of weight and rate of gain with age at puberty were significant at all stages between 98 and 168 days in 3 lines, significant at most stages in the AK line and significant at only 1

TABLE 5. MULTIPLE CORRELATIONS OF WEIGHT AT DIFFERENT AGES AND GAINS IN WEIGHT DURING THE SUBSEQUENT 14 DAYS WITH AGE AT PUBERTY IN 1949 BOARS

Age (days)	Line and Number of Animals					X^2 (Lines)
	AK (13)	MA (20)	PM (21)	York (10)	CY (31)	
98	.81**	.73**	.61*	.85*	.74**	1.77
112	.86**	.72**	.49	.86*	.72**	4.70
126	.92**	.74**	.39	.94**	.72**	13.30**
140	.30	.73**	.30	.86*	.73**	16.46**
154	.48	.79**	.29	.92**	.73**	10.84*
X^2(Ages)	11.51*	0.24	2.20	1.11	0.05	

* $P \geqq 0.05$.
** $P \geqq 0.01$.

stage (98 days) in the PM line (table 5). Within lines the size of the correlations varied significantly at different stages in the AK line but not in the other 4 lines. However the differences in the size of the correlations in different lines were significant at 3 stages, 126, 140 and 154 days.

Age at Puberty in Relation to Stage of Season When Farrowed

Simple correlation coefficients between stage of farrowing season (number of days from March 1 to farrowing) and age at puberty were computed for each line each year. The correlations were insignificant in all lines in both years with one exception (1949 CY) (table 7). Likewise stage of farrowing season was not always associated with age at puberty in gilts in this herd (Warnick *et al.*, in press) in the same years. However season of birth has been reported

TABLE 6. AGE AT PUBERTY IN BOARS "SELECTED" AND "NOT SELECTED" AS POTENTIAL BREEDING BOARS AT WEANING TIME

Line	Number of Animals		56 Day Weight		154 Day Weight		Age at Puberty	
	"Selected"	"Not Selected"	"Selected"	"Not Selected"	"Selected"	"Not Selected"	"Selected"	"Not Selected"
AK	6	7	28	20	131	79	159	239
MA	13	7	28	21	108	86	198	234
PM	8	13	27	20	109	85	184	191
York	5	5	30	24	104	54	141	277
CY	17	14	30	18	115	73	185	231
Total or Unweighted Mean	49	46	29	21	113	75	173	234

to have an effect on the time of laying of the first egg in chickens (Upp and Thompson, 1927) and in pigeons and doves (Riddle, 1930) and on the age at puberty in outbred gilts (Wiggins *et al.*, 1950; Robertson *et al.*, Unpublished data, University of Wisconsin). Both boars and gilts in this herd were variable in health and thriftiness in both years and it is possible that other factors masked the effect of stage of season when farrowed on the age at puberty in both males and females.

Fertility Tests

Fertility tests were made on 15 animals that were to be used in the inbred herd and in the herds of cooperating breeders. Semen

TABLE 7. CORRELATION BETWEEN FARROWING DATE AND AGE AT PUBERTY IN BOARS

Line	Number of Animals		Number of Days after March 1 to Farrowing				Correlation Between Farrowing Date and Age at Puberty	
			Range		Average			
	1948	1949	1948	1949	1948	1949	1948	1949
AK	5	13	32–37	7–44	34.0	22.3	+.58	+.48
MA	8	20	30–57	1–51	36.7	24.9	−.15	+.28
PM	11	21	4–32	8–51	14.4	19.1	−.16	+.23
York	8	10	5–38	5–49	23.9	33.2	+.43	−.19
CY	9	31	6–18	4–42	12.7	9.2	−.52	+.48**

** $P \geq 0.01$.

was collected by artificial vagina and gilts that had been in estrus for less than 24 hours were inseminated with the total fluid portion of the ejaculate (undiluted) usually within 2 hours and never more than 3 hours after collection. Boars that produced 50% or more cleaved eggs in the gilts to which they were bred were considered to be fertile and no further tests were made. Boars that were not fertile on the first test were then used in inseminating another gilt. Eleven of the 15 tested boars (73%) were found to be fertile on the first test; the average of the fertilization rates in the gilts to which they were bred was 83% (table 8). These boars ranged from 169 to 236 days of age at the time of testing and their average age was 211 days. Three boars were not demonstrated as fertile until a second test at an average age of 236 days. The average of the fertilization rates in their mates was 95%. One boar was bred to 7 gilts before he was found to be fertile although his semen, from the standpoint of sperm concentration, percent motile sperm and percent normal sperm (morphologically), was above the average of all boars tested.

In 1949 it was not possible to make fertility tests but the semen of 38 boars was examined for the presence of sperm on the day of first mating. These boars were allowed to mate a gilt whose uterine horns had been sectioned and ligated just anterior to the junction of the uterine body and the uterine horns. The semen which flowed back during mating was collected and examined. The semen of 30 of the 38 boars contained sperm on the day of first mating. In 7 of the others only a few drops of semen were collected and it is possible that their semen would have been found to contain sperm had better samples been collected. All of these boars were found to have sperm when examined again 1 to 2 weeks later. Sperm were not found in the semen of the remaining boar until 5 weeks after puberty

TABLE 8. RESULTS OF FERTILITY TESTS IN YOUNG BOARS

Item	Number of Boars	Age at Time Fertility Was Established		Unweighted Average Percentage of Cleaved Eggs on Fertility Test
		Range	Average	
Fertile on first test	11	169–236	211	83
Fertile on second test	3	227–241	236	95
Fertile on seventh test	1	.....	333	100

although 4 samples of 20 to 50 cc. each were examined during the 5 week interval.

Twelve boars that would not yet mate at 335 days were biopsied and found to have sperm in their testes. Three of these were in the AK line, two in the MA, none in PM, two in the York and five in the CY.

Discussion

The average ages of the boars at puberty in this herd were 196 days in 1948 and 205 days in 1949. In comparison the average ages of the gilts at puberty were 236 and 251 days (Warnick *et al.*, in press). This suggests that in swine the male is the precocious sex as far as puberty is concerned.

No histological studies were made but if these boars were similar to those studied by Phillips and Andrews (1936), Phillips and Zeller (1943), and Andrews and Warwick (1949) in which sperm were found in the testes at ages of 110 to 147 days it would appear that sperm are present in the testes for some time before libido is pro-

nounced enough that the animals will mate within 15 minutes after being placed with an estrual gilt.

In 1948 when only the heavier, more thrifty boars at weaning furnished information on age at puberty the correlations between weight at 56 days and age at puberty and between weight at 154 days and age at puberty were not significant. Likewise in outbred Poland China and Chester White gilts in which the variation in health and thriftiness were not extreme Robertson *et al.* (Unpublished), did not find a significant association between weight at any age between 98 and 168 days and age at puberty. There was, however, a significant negative correlation between stage of season when farrowed and age at puberty. On the other hand in inbred boars in 1949 and in inbred gilts in 1948 and 1949 where there was extreme variability in health and thriftiness, age at puberty was significantly associated with weight at various prepuberal stages, but not with stage of season when farrowed. More data are needed on the relation of weight at prepuberal stages to age at puberty in both sexes in both inbred and outbred herds under different controlled environmental conditions. If there is a general tendency for the heavier pigs at 56 and 154 days to reach puberty earlier than lighter pigs some progress could be made by selecting indirectly for early puberty on the basis of body weight. This would be particularly desirable in boars because pigs not intended for breeding could be castrated early. If, on the other hand, no relationship exists between weight and age at puberty except in special cases of extreme variability in health and thriftiness or if there is even a tendency for the lighter pigs at certain ages to reach puberty first, direct selection for early puberty must be practiced. More data are also needed to clarify the relationship between stage of season at birth and age at puberty.

The data of Warnick *et al.* (in press), and Robertson *et al.* (Unpublished), show that gilts that have had one or more heat periods before breeding ovulate more eggs and farrow more pigs than gilts bred at their puberal heat. The data of Hauser *et al.* (1949), indicate that sperm concentration increases in the semen of young boars with advancing sexual age. Thus it appears that early puberty is an important economic character in swine.

Summary

Ages at puberty (ability and willingness to mate within 15 minutes after being exposed to an estrual gilt) were obtained on 136 inbred boars of Chester White and Yorkshire ancestry in a 2 year period. Average ages at puberty were 196 days for 41 boars selected at

weaning for breeding purposes in 1948 and 205 days for 95 unselected boars in 1949. Corresponding average weights at puberty were 166 and 141 pounds.

Weights at 56 and 154 days in 1948 were not significantly associated with age at puberty in any line. In 1949 weights at all ages from 56 to 168 days were significantly correlated with age at puberty in 4 of the 5 lines. There was also a significant negative correlation between rates of gain during successive 14 day periods from 98 to 168 days and age at puberty in these same 4 lines.

The correlations between stage of season when farrowed and age at puberty were insignificant in all lines in both years with only one exception.

Fertility tests were made (artificial insemination) on 15 boars in 1948. Eleven boars were found to be fertile on the first test (50% or more cleaved eggs in their mates 1 to 2 days after heat) at an average age of 211 days (not tested at an earlier age). Three more were fertile on second test at an average age of 236 days. The remaining boar was tested 7 times before he was found to be fertile at 333 days of age.

Sperm were found in the semen of 30 of 38 boars on the day of first mating in 1949 and in 7 others within 2 more weeks. Sperm were not found in the semen of the remaining boar for 5 weeks after puberty.

Literature Cited

Andrews, F. N. and E. J. Warwick. 1949. Comparative testicular development of some inbred, purebred, crossbred and linecross boars. JOURNAL OF ANIMAL SCIENCE 8:603 (Abstract).

Hauser, E. R., C. D. Squires, G. E. Dickerson and D. T. Mayer. Inbreeding and strain differences in reproductive performance of boars. JOURNAL OF ANIMAL SCIENCE 8:640 (Abstract).

Phillips, R. W. and F. N. Andrews. 1936. The development of the testes and scrotum of the ram, bull and boar. Mass. Agr. Exp. Sta. Bul. 331.

Phillips, R. W. and J. H. Zeller. 1943. Sexual development in small and large types of swine. Anat. Rec. 85:387.

Rice, V. A. 1942. Breeding and improvement of farm animals. 3rd ed. McGraw-Hill Book Co., Inc., New York.

Riddle, Oscar. 1931. Studies on the physiology of reproduction in birds XXIX. Season of origin as a determiner of age at which birds become sexually mature. Amer. Jour. Physiol. 97:581.

Upp, C. W. and R. B. Thompson. 1927. Influence of time of hatch on hatchability of the eggs, rate of growth of the chicks and characteristics of the adult female. Okla. Agr. Exp. Sta. Cir. 67.

Warnick, A. C., E. L. Wiggins, L. E. Casida, R. H. Grummer and A. B. Chapman. 1951. Variation in puberty phenomena in gilts. JOURNAL OF ANIMAL SCIENCE. (in press)

Wiggins, E. L., L. E. Casida and R. H. Grummer. 1950. Effect of season of birth on sexual development in gilts. JOURNAL OF ANIMAL SCIENCE 9:277.

HETEROSIS IN CROSSES OF INBRED LINES OF DUROC SWINE

DOYLE CHAMBERS AND J. A. WHATLEY, JR.
Oklahoma A. and M. College[1]

BETWEEN 1938 and 1949 seven different unrelated inbred lines of Duroc swine were developed by the Oklahoma Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory. In sixteen of the twenty-two farrowing seasons from the spring of 1939 through the fall of 1949, both inbred and two-line-cross litters were produced. In some seasons outbred Duroc and three-line-cross litters were farrowed.

The purpose of the present study was to determine if selection within moderately inbred Duroc lines followed by crossing of these lines resulted in improved performance. If so, its manner of expression and the time at which it was first evident were to be investigated.

Source of Data and Method of Analysis

Line 3 is the only line regularly represented throughout the period covered by this study. The average inbreeding for the line rose from almost zero in 1939 to approximately 25 percent in 1949. Line 1 was the most highly inbred line (approximately 37%) used in the study; and, contrasted with other lines, the average inbreeding of this line did not vary greatly from season to season. Because of the high mortality and slow growth of the inbred pigs, this line was discarded in 1946. All other lines were less than 20 percent inbred during the time they were in the line-crossing tests. Except for line 7, which was formed by crossing lines 1 and 6, none of the lines were related. Line 7 was never crossed with either of the two parent lines as they were discontinued before line 7 was used in crosses.

The rations and systems of management have changed slightly from season to season, but the various lines and crosses received comparable treatment within the same season. No serious outbreaks of disease occurred during any of the seasons included in this study. Since rotation of pastures proved inadequate for the control of internal parasites, routine treatment for roundworms was practiced during the last five years.

[1] Animal Husbandry Department, in cooperation with the Regional Swine Breeding Laboratory (Ames, Iowa), Bureau of Animal Industry, Agricultural Research Administration, U.S.D.A.

Birth and 56-day records were included for 444 litters; 21- and 180-day records were available for 371 litters of these. In 1949 the recording of 21-day weights was discontinued, and the 180-day records were not included because the pigs in all litters were not fed under the same conditions from weaning to 180 days. Litter weights and number of live pigs per litter at birth, 21, 56, and 180 days were the items considered when comparing the performance of various lines and crosses.

A preliminary analysis of the data revealed that the dams of the inbred litters averaged approximately four months older than the dams of non-inbred litters. This was because a higher proportion of older sows was bred to produce inbred litters than non-inbred litters. In order to minimize this source of bias, a set of correction factors was computed from the data. All sow litters were corrected to a gilt equivalent age, using the factors which are given in table 1. These

TABLE 1. CORRECTION FACTORS USED FOR CORRECTING SOW LITTERS TO GILT EQUIVALENT AGE

Age of Sows	No. Litters		At Farrowing			21 Days		56 Days		180 Days	
	Sow	Gilt	Total No.	Live Pigs	Live Wt.	No.	Wt.	No.	Wt.	No.	Wt.
1.0			1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.5	105	183	.821	.803	.731	.879	.813	.881	.776	.855	.766
2.0	66	152	.760	.766	.693	.920	.798	.909	.759	.871	.796
2.5	37	93	.705	.753	.649	.862	.772	.875	.746	.847	.774
Mean Performance[1]			7.85	7.38	17.85	6.09	57.4	5.90	145.6	5.17	769.0
Ave. wt. per pig					2.42		9.43		24.7		148.7

[1] Mean performance of 371 litters corrected to a gilt equivalent age.

factors were obtained by computing the weighted mean differences between the gilt litters and those from the sows of the various age groups. Comparisons were confined to those which occurred within the same season. A separate set of factors was obtained for sows raising inbred and non-inbred litters in order to avoid confounding age of dam with breeding of the litter. Although the differences were somewhat larger between the age groups when sows and gilts were producing inbred litters than when they were producing non-inbred litters, the two groups of data were pooled to obtain the factors used in this study. If the use of these factors was a source of error, the bias was relatively small and in favor of the inbred litters.

Some of the important sources of variation which may have affected litter weight and number of pigs per litter, other than the breeding of the litter and age of the dam, were: (1) seasonal fluctuation in environment and changes in management from season to season, (2) differ-

ences in maternal abilities which may be characteristic of different lines, and (3) differences in the coefficients of inbreeding among sows of the same line. The analysis was restricted to comparisons within the same season. This restriction automatically reduced the mean differences in the coefficients of inbreeding among the sows of the same line.

There were unequal numbers of litters in the various breeding groups and seasons. Dickerson (1946) used a method suggested by Yates (1934) on similar data at the Iowa Station and suggested its use in the present investigation. This procedure weights the mean differences in proportion to the reciprocal of the variance.

TABLE 2. DISTRIBUTION OF LITTERS BY LINE OF DAM AND SEASON FOR COMPARISON I

Season Farrowed	Line of Dam	Number of Litters			
		Comparison I		Test Litters	
		Inbreds	Two-line Crosses	Inbreds	Two-line Crosses
'39S	3	9	4	3	2
'39F	1	5	1	..	..
	3	6	7	3	2
'40S	2	..	..	2	1
'40F	3	5	2	3	2
	1	..	..	2	1
'41S	3	10	2	6	2
	2	..	..	1	1
'41F	1	5	7	1	5
	3	10	4	4	3
	4	..	..	3	2
'42F	1	3	5	..	..
	3	9	5	1	4
'43S	1	4	3	..	..
	3	11	3	2	4
'43F	3	7	7	..	..
'44S	3	..	..	5	2
'44F	3	5	7	..	..
'45S	1	3	5	..	..
	3	6	11	..	..
'45F	3	10	4	4	2
	6	4	5	..	..
'46S	3	9	7	..	..
'47F	3	5	4	2	1
	5	6	7	2	3
	7	4	3	2	2
'48F	3	3	6	2	3
	5	3	6	2	4
	7	2	5	2	3
Total		144	120	52	49

Results

The study was divided into five different comparisons, each producing information of a different nature. Although some of the litters were used in more than one comparison, it was not felt that conclusions drawn would be affected. The results of each comparison will be presented separately.

TABLE 3. INTRA-SEASON WEIGHTED MEAN DIFFERENCES BY COMPARISON GROUPS (AGE OF SOW CORRECTED TO ONE YEAR)

Items	Comparisons[1]				
	I	II	III	IV	V
Percentage inbreeding					
Litters	—22	—26	0	0	0
Sire	14	8	—14	13	29
Dam	0	—5	—24	0	25
At birth					
Total number of pigs	0.58	0.74	1.64**	0.93	—0.97
No. live pigs	0.43	0.48	1.36*	1.17*	—0.92
Live wt. litter (lbs.)	1.22	1.68	2.94*	2.75*	—2.01
At 21 days					
No. pigs	0.76*	0.74	1.15*	1.60	—0.39
Litter wt. (lbs.)	7.42	8.76	9.55*	13.01	—5.31
At 56 days					
No. pigs	0.85*	0.88	1.20*	1.49	—0.28
Litter wt. (lbs.)	23.50*	30.21	29.68*	24.73	—13.34
At 180 days					
No. pigs	1.08**	1.31	1.66	2.19	—0.35
Litter wt. (lbs.)	180.9**	235.0	297.8*	348.8	—13.5

* Denotes significance at the 5% level of probability.
** Denotes significance at the 1% level of probability.
[1] Comparison I. Two-line crosses minus inbreds within line of dam.
Comparison II. Two-line crosses minus average of two parental inbred lines.
Comparison III. Three-line crosses minus two-line crosses.
Comparison IV. Three-line crosses minus outbred Durocs.
Comparison V. Two-line crosses minus outbred Durocs.

Comparison I. Two-line Crosses Versus Inbreds Within Line of Dam

The intraseason weighted mean differences between inbred litters and two-line-cross litters with the same line of dam were computed for each of the items studied. This comparison gives an estimate of the effect of the heterozygosity of the pigs on litter performance when line and inbreeding of the dams are the same. There were 144 inbred litters and 120 two-line-cross litters in 14 seasons. The distribution of these litters by season and line of dam is presented in table 2. The advantage of the two-line-cross litters over the inbred litters with the same line of dam is given in table 3.

The inbred pigs were inbred approximately 22 percent, while the two-line-cross litters were not inbred. There was no difference in the average inbreeding of the dams of the two groups of pigs. The two-line-cross litters were heavier at birth, 21, 56, and 180 days by 1.22, 7.42, 23.5, and 180.9 pounds respectively. At the same ages the two-line-cross litters contained 0.43, 0.76, 0.85, and 1.08 more live pigs than the inbred litters. These weighted mean differences were then

TABLE 4. MEAN PERFORMANCE OF INBREDS (COMPARISONS I, II), TWO-LINE CROSSES (COMPARISON III) AND OUTBREDS (COMPARISONS IV, V) TOGETHER WITH PERCENTAGE ADVANTAGE OF TWO-LINE CROSSES (COMPARISONS I, II, V) AND THREE-LINE CROSSES (COMPARISONS III, IV)

Items	Number Litters	Number Seasons	Number Live Pigs per Litter and Litter Weights (lbs.)							
			Birth		21 Days		56 Days		180 Days	
			No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.
Comparison I										
Mean—Inbreds	144	14	7.1	17	5.6	53	5.4	131	4.6	669
2-line Cross (% Adv.)	120	14	6	7	14	14	16	18	24	27
Comparison II										
Mean—Inbreds	127	10	7.1	17	5.6	51	5.2	124	4.4	607
2-line Cross (% Adv.)	76	10	7	10	13	17	17	24	30	39
Comparison III										
Mean—2-line Cross	74	5	7.3	18	6.4	61	6.3	159	5.7	889
3-line Cross (% Adv.)	24	5	19	17	18	16	19	19	29	34
Comparison IV										
Mean—Outbreds	14	3	8.0	19	6.4	57	6.4	153	5.7	795
3-line Cross (% Adv.)	23	3	15	14	25	23	23	16	39	44
Comparison V										
Mean—Outbreds	31	7	8.4	20	6.7	64	6.7	169	5.6	754
2-line Cross (% Adv.)	95	7	−11	−10	−6	−8	−4	−8	−6	−2

expressed as percentage advantages of the two-line-cross litters over the inbred litters within line of dam. The mean performance of the inbred litters and the percentage advantage of the two-line-cross litters are given in table 4. These are graphically presented in figure 1. This figure reiterates that the differences in litter weights were due largely to the increased viability of the two-line-cross pigs.

During twelve of the seasons, two-line-cross and inbred pigs within the same line of dam were placed on record of performance tests shortly after weaning. Usually, four pigs from each litter tested were fed a standard ration in dry lot from weaning to approximately 225

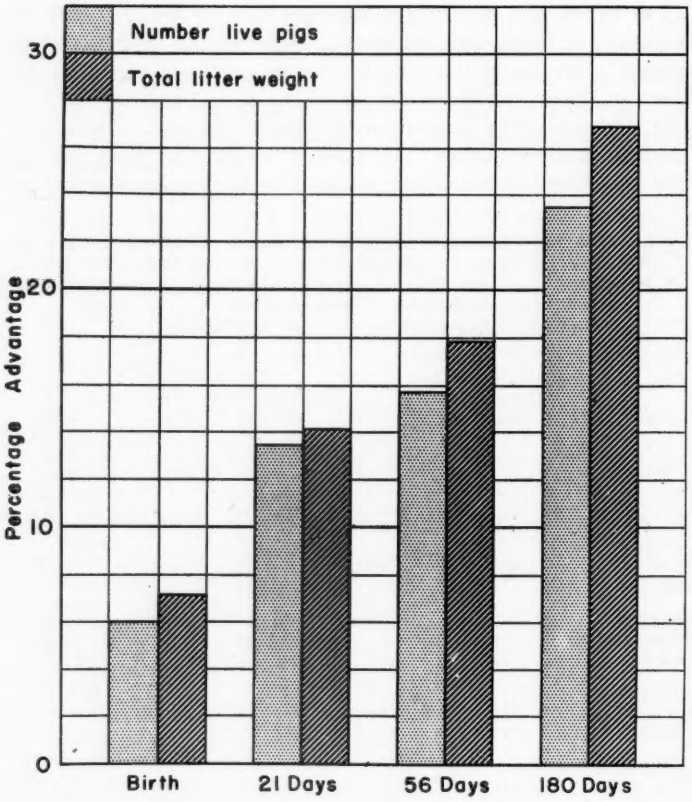


Figure 1. Percentage advantage of two-line-cross litters over inbred litters within line of dam.

pounds weight. The distribution of the 49 two-line-cross and 52 inbred litters by line of dam and season is given in table 2. There was no difference in the average initial weights of the two groups of test pigs nor the average inbreeding of their dams. The two-line-cross pigs gained 0.03 of a pound per day more rapidly than did their inbred counterparts. They required six pounds less feed per 100 pounds of gain than did the inbreds. These differences were not significant at the commonly accepted level of probability. However, the increased rate of gain found here checked closely with the increased litter

performance in Comparison I, after the increased number of pigs per litter had been considered. Dickerson and others (1946) at the Iowa Station, studied the differences between two-line-cross litters and inbred litters by the same boar in the Poland China breed. The differences were expressed as decline per 10 percent inbreeding of the litter. This decline amounted to 0.26, 0.35, 0.37, and 0.39 of a pig per litter at birth, 21, 56, and 154 days. When comparable figures were obtained for the same items in Comparison I of the present investigation, the decline amounted to 0.27, 0.35, 0.39, and 0.49 of a pig per litter at birth, 21, 56, and 180 days for each 10 percent inbreeding of the litter. Differences in litter weights were also in close agreement at the two stations. The Iowa workers also fed out a sample of their two-line-cross and inbred pigs from 84 days to a final weight of 225 pounds. When the differences between the two groups were adjusted to zero difference in initial weight and total gain, the advantage of the two-line-cross pigs was only 0.03 of a pound per day in rate of gain. They found no evidence of a difference in efficiency of gain.

Comparison II. Two-line Crosses Versus the Average Performance of the Two Parental Inbred Lines

There were ten seasons in which two-line-cross litters and inbred litters of both the parental lines were produced. There were 76 two-line-cross litters and 127 inbred litters. The weighted mean differences within season for the number of pigs per litter and for total litter weights at the four ages are given in table 3. The differences in favor of the two-line-cross litters were somewhat greater in this comparison than in Comparison I. However, the mean performance of the inbred litters (table 4) was lower in Comparison II than in Comparison I, because the more highly inbred lines were used more frequently in the crosses as the sire than as the dam. All of the two-line-cross litters and part of the inbred litters in Comparison II had been included in Comparison I. It was again noted that the advantage of two-line-cross litters increased with the age of the pigs. Between 70 and 80 percent of the increased litter weight at the different ages could be attributed to an increased number of live pigs per litter.

Comparison III. Three-line Crosses Versus Two-line Crosses

Some of the two-line-cross gilts were bred to an inbred boar of another line and produced litters designated as three-line-cross litters. During five seasons, 24 three-line-cross litters occurred together with 74 two-line-cross litters. A direct comparison of the two groups gave an

estimate of the effect of the heterozygosity of the dam in combination with that of the litter. Neither of the groups of pigs was inbred, but the two-line-cross litters were farrowed and nursed by sows which were inbred approximately 24 percent. The three-line-cross litters were farrowed and nursed by two-line-cross sows and benefited from any heterosis expressed in the form of increased productivity of the dam. The weighted mean differences in number of pigs per litter

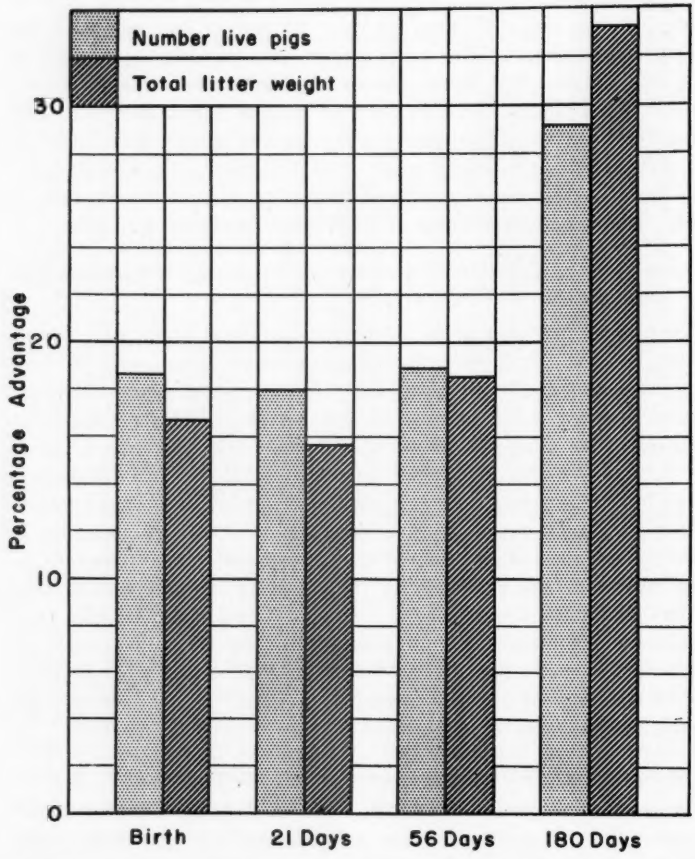


Figure 2. Percentage advantage of three-line-cross litters over two-line-cross litters.

and in litter weights at all ages (table 3) were quite large and very consistent from season to season in favor of three-line-cross litters. In litter weight the three-line crosses exceeded the two-line crosses by 2.9 pounds at birth, 9.6 pounds at 21 days, 29.7 pounds at 56 days and 298 pounds at 180 days. Their advantage in number of live pigs per litter at the same ages was 1.36, 1.15, 1.20, and 1.66. When these differences were converted to percentage increases (table 4) over the mean performance of the two-line-cross litters, a striking difference between these results and those from the two preceding comparisons became apparent. This is shown in figure 2. At birth, 21 days, and 56 days the three-line-cross litters showed a greater proportional advantage in number of live pigs per litter than in litter weight. At 180 days, however, a 29 percent increase in number of live pigs per litter was associated with a 34 percent increase in litter weight. Apparently the larger number of live pigs per litter in the three-line-cross litters had been great enough to reduce the pre-weaning growth rate of the individual pig below that of pigs in two-line-cross litters in which there were fewer pigs. The fact that they gained more rapidly between weaning and 180 days of age indicates that the three-line-cross pigs had the ability to gain as rapidly as two-line crosses, but that their pre-weaning environment was not optimum for maximum growth. The superiority of the three-line-cross litters at this station in litter size and weight was similar to that of three-breed crosses reported by Winters *et al.* (1935), Lush and co-workers (1939) and by Robison (1948).

Comparison IV. Three-line Crosses Versus Outbred Durocs

During three seasons, three-line-cross litters occurred together with outbred Duroc litters. Since only 23 three-line-cross litters and 14 outbred Duroc litters were involved, conclusions drawn must be tentative. However, the differences are given in table 3; and with the other comparisons, this one adds information which is needed in arriving at methods for the use of inbred lines.

In Comparison IV neither the litters nor their dams were inbred. The sires of the three-line crosses were from moderately inbred lines. The outbred litters were sired by non-inbred boars. The differences were again in favor of the three-line-cross litters. The magnitude of the differences was roughly the same as the advantage of three-line crosses over two-line-cross litters in Comparison III. The increased number of live pigs again was greater than the increased litter weights at birth, 21, and 56 days of age (table 4). At 180 days there were

not only more live pigs per litter but the individuals had gained at a faster rate. Therefore, the three-line-cross litters were nearly 350 pounds heavier than outbred litters at six months of age. The differences in Comparisons III and IV may be larger than would have been obtained if all the possible three-line crosses had been made. They do indicate, however, that selected lines may be used in crosses to raise the level of performance of swine in certain economically important traits.

Comparison V. Two-line Crosses Versus Outbred Durocs

Ninety-five two-line-cross and 31 outbred Duroc litters were produced during seven of the seasons so that they could be compared directly. The weighted mean differences, although very inconsistent from season to season, were slightly in favor of the outbred Duroc litters (table 3). Analysis of the data indicated no more than sampling variations between the two groups at all ages, both for number of pigs per litter and for total litter weight. The mean differences between the two groups in this case became smaller as the age of the pigs increased. There was even some indication that the two-line-cross pigs were gaining more rapidly after weaning than the outbreds. At weaning the two-line-cross litters contained 4 percent fewer pigs and weighed 8 percent less than outbred litters (table 4); at 180 days these two-line-cross litters contained 6 percent fewer pigs and weighed 2 percent less than the outbred controls.

Summary

The litter weights and number of live pigs per litter for 371 litters of Duroc swine at birth, 21, 56, and 180 days of age were studied. The same items were studied on 73 additional litters at birth and 56 days. All litters were farrowed at the Oklahoma Agricultural Experiment Station during the period from 1939 to 1949 inclusive. The study included inbred litters from seven different lines, as well as two-line-cross, three-line-cross, and outbred Duroc litters. Intra-season weighted mean differences were obtained for number of pigs per litter and litter weights at birth, 21, 56, and 180 days for five different comparisons.

The comparisons made were: I, two-line-cross litters with inbred litters within line of dam; II, two-line-cross litters with the average of the two parental inbred lines; III, three-line-cross litters with two-line-cross litters; IV, three-line-cross litters with outbred Duroc litters; V, two-line crosses with outbred Durocs. The data on litters

produced by sows over one year of age were corrected to a gilt-equivalent age.

Hybrid vigor was evident both in number of pigs per litter and litter weights at birth, and increased as the litters became less dependent upon the direct mothering ability of the dams.

This vigor was expressed to a greater extent in the increased viability of the pigs and productivity of two-line-cross gilts than in the increased growth rate of the individual pigs.

There was no significant difference in the performance of two-line-cross litters raised by inbred sows and the performance of outbred Duroc litters which were produced in the same season.

Three-line-cross litters, raised by two-line-cross dams and sired by inbred boars of a third line, were superior to both two-line-cross and outbred Duroc litters with which they were compared. The differences were not statistically significant for all items.

Increased number of pigs per litter in most cases was sufficient to account for a large percentage of the increase in total litter weight.

When initial weights of the pigs were the same, advantages of two-line-cross pigs over inbreds with the same line of dam in post-weaning rate of gain and efficiency of gain were relatively small and inconsistent.

Because heterosis was expressed in both number of pigs which survived and the growth rate of the individual, total weight of the litter seems to be the one best over all measure of performance for comparison of lines or crosses.

Literature Cited

Dickerson, G. E., J. L. Lush, and C. C. Culbertson. 1946. Hybrid vigor in single crosses between inbred lines of Poland China swine. JOURNAL OF ANIMAL SCIENCE 5:16.

Lush, J. L., P. S. Shearer, and C. C. Culbertson. 1939. Crossbreeding hogs for pork production. Iowa Agr. Expt. Sta. Bul. 380.

Robison, W. L. 1948. Crossbreeding for the production of market hogs. Ohio Agr. Expt. Sta. Bul. 675.

Winters, L. M., O. M. Kiser, P. S. Jordan, and W. H. Peters. 1935. A six years study of crossbreeding swine. Minn. Agr. Expt. Sta. Bul. 320.

Yates, F. 1934. The analysis of multiple classifications with unequal numbers in the different classes. Jour. Amer. Stat. Assoc. 29:51.

INHERITANCE OF SCROTAL HERNIA IN SWINE[1]

W. T. MAGEE[2]
Iowa State College

SCROTAL hernia is the protrusion of the intestine or of any other organ into the scrotum, usually through the inguinal canal. Herewith are presented some pertinent findings from a study of the incidence of scrotal hernia among the inbred lines of swine maintained by the Iowa Agricultural Experiment Station.

Warwick (1926, 1931) conducted the most extensive breeding experiments yet reported on hernia in swine. After selecting for hernia for 3 generations, he concluded that inguinal hernia is definitely heritable.

Material and Methods

A herd of inbred swine was established at the Iowa Agricultural Experiment Station in 1930. The herd was expanded to twelve Poland China lines and one Danish Landrace line by 1938. The data from 1938 to and including the fall of 1947 were used in this study.

During this period 1597 litters were produced which contained one or more male pigs alive at weaning age. The number of male pigs alive at weaning was studied, rather than the number born, because some cases of hernia were not observed until the pigs were examined carefully at weaning time. These litters contained 4135 male pigs. Two hundred and ten of these pigs were herniated as follows: left, 155; right, 36; double hernia or side not recorded, 19. The inbreeding of the lines averaged about 15 percent in 1938, and about 40 percent in 1947. Selection against hernia was always practiced in this herd. No herniated boars were ever used as herd sires. Only rarely were litter mates of herniated pigs used as breeding stock.

The statistical procedures used in the analysis were chiefly the chi-square analysis and the analysis of variance. Each herniated pig was given a value of one and each normal male pig was given a value of zero. This method was used by Lush, Lamoreux and Hazel (1948) in studying mortality in poultry. For estimating the variance com-

[1] Journal Paper No. *J 1936* of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. *1127*.
[2] The assistance of Dr. J. L. Lush and Dr. L. N. Hazel is gratefully acknowledged.

ponents and heritability, the method of C. R. Henderson (1948) was used.

Results

The incidence of hernia for the herd during this period averaged 5.1 percent. It was about 9 percent in 1938 and about 6 percent in the spring of 1947, but has ranged between 2 and 9 percent in different years. A linear regression showed a decline of only 0.04 percent per

TABLE 1. INCIDENCE OF HERNIA BY LINES

Line	Number of Boar Pigs	Number with Hernia	Fraction with Hernia
A	472	14	.030
B	343	2	.006
C	229	6	.026
D	160	2	.012
E	205	30	.146
F	213	0	.000
G	256	5	.020
H	293	22	.075
I	224	6	.027
J	217	34	.157
K	115	12	.104
S	965	46	.048
L	443	31	.070
	4135	210	.051

year. Since this is very small and statistically insignificant, the incidence of hernia probably has not really changed during this period.

The average incidence of hernia among the 13 lines varied from 0 to more than 15 percent (table 1). These differences between lines are almost certainly real because the chi-square of 149 with 12 degrees of freedom is far beyond the 0.01 level of significance.

Variance components were calculated for lines, years, line-year interaction, sires, and dams (table 2). These estimates were denoted as σ_T^2, σ_A^2, σ_{AT}^2, σ_B^2 and σ_S^2, respectively. It is easy to solve for σ_E^2, σ_S^2 and σ_B^2 in table 2 because the equations containing only these may be solved by substituting values found in the equations below the equation to be solved. However, the nonorthogonality of the line-by-year classification causes some of the year effects to be in the equation for line effects. To solve for σ_A^2, σ_T^2, σ_{AT}^2, the three equations

containing them were solved by iteration, after the estimated value of σ_E^2, σ_S^2 and σ_B^2 were substituted into the equations. The answers obtained by the iteration were σ_T^2=.00167, σ_{AT}^2=.00004, σ_A^2= .00007. This shows that the year effect and year-line interaction are very small, and could easily be due to sampling errors. Therefore, σ_T^2,

TABLE 2. COMPOSITION OF THE MEAN SQUARES

Source of Variation	d.f.	Mean Square	Components in the Mean Squares
Total	4134	.0482	
Between lines	12	.5991	$\sigma_E^2+3.2\sigma_S^2+13.7\sigma_B^2+25.6\sigma_{AT}^2+306.4\sigma_T^2+5.1\sigma_A^2$
Between years	19	.0800	$\sigma_E^2+3.3\sigma_S^2+13.1\sigma_B^2+29.0\sigma_{AT}^2+6.9\sigma_T^2+202.7\sigma_A^2$
Line × year interaction	185	.0743	$\sigma_E^2+3.0\sigma_S^2+10.0\sigma_B^2+17.5\sigma_{AT}^2-.7\sigma_T^2-.3\sigma_A^2$
Between boars (within lines)	218	.0710	$\sigma_E^2+2.8\sigma_S^2+8.5\sigma_B^2$
Between sows (within boars)	1162	.0586	$\sigma_E^2+2.5\sigma_S^2$
Within litters	2538	.0368	σ_E^2

$$\sigma_S^2=\frac{.0586-.0368}{2.5}=0.0088$$

$$\sigma_B^2=\frac{.0710-.0368-(8.5)\,(.0088)}{8.5}=0.0012$$

which expresses the size of the real differences between lines, was calculated on the assumption that σ_{AT}^2 and σ_A^2 were zero and was found to be only .00001 smaller than when σ_A^2 and σ_{AT}^2 were considered.

Heritability of individual differences within lines was estimated from the relative size of σ_E^2, σ_S^2 and σ_B^2, but these were measured on an intra-line basis and the inbreeding which had been practiced in making these lines had probably extinguished part of the genetic variability which was within these lines initially. To make these findings more applicable to purebred but non-inbred populations, it

seems advisable to allow for the probable effect of inbreeding on the genic variance in the actual data. This can be shown as:

Observed Variance Components	Amount of the Original Genic Variance Contained in Each
Total	$(1+F)\ V(G)$
Between lines	$2F \cdot V(G)$
Within lines	$(1-F)\ V(G)$
Between sires	$\frac{1+F'-2F}{4} V(G)$
Between dams	$\frac{1+F'-2F}{4} V(G)$
Between litter mates	$\frac{1-F'}{2} V(G)$

Where $V(G)$=original genic variance
F and F'=inbreeding in the present and preceding generations, respectively.

Two methods of calculating from these data on partially inbred lines what the heritability would be in the random bred population from which they arose and of which they may be considered as samples, modified by some inbreeding, are as follows:

From σ_B^2
Heritability=0.15
From the genetic differences between the inbred lines
Heritability=0.07

The former is much more dependable, since there were 218 degrees of freedom between boars within lines but only 12 between lines.

An estimate of maternal effect, over and above the genes a sow transmits to her offspring, is obtained by assuming that the sire effect, σ_B^2, is all additively genetic and that the sire and dam have equal additively genetic effects. Then the maternal effect, the extra effect of the dam, is estimated as:

$$\frac{\sigma_S^2-\sigma_B^2}{\sigma_P^2=\sigma_E^2+\sigma_S^2+\sigma_B^2+\sigma_T^2+\sigma_A^2+\sigma_{AT}^2}=0.157$$

This means that 15.7 percent of the variance in the incidence of scrotal hernia is due to the extra effect of the dam. It may be genetic or environmental. It would be genetic to the extent that some inherited qualities in the dams make them provide variable environments some of which favor while others prevent the occurrence of hernia in the

pig which develop in their bodies or are nursed by them. It could also be genetic, in the broad sense, to the extent that dominance or overdominance deviations contribute anything to litter-mate correlations. In these data the maternal effect could not be separated further into genetic and environmental portions, since the maternal half sibs were too rare to be useful for comparison with paternal half sibs and with full sibs.

The correlation between litter mates is $\frac{\sigma_S^2+\sigma_B^2}{\sigma_S^2+\sigma_B^2+\sigma_E^2}=.21$ on an intra-line basis, or $\frac{\sigma_S^2+\sigma_B^2+\sigma_T^2}{\sigma_S^2+\sigma_B^2+\sigma_E^2+\sigma_T^2}=.24$ in the whole set of data. What such a correlation means in terms of herniated pigs may be illustrated by the frequencies of hernia in those litters which had two male pigs at weaning. The actual frequencies and those expected, if the actual frequency of hernia were the same but there were no correlation between litter mates, were as follows:

	Actual	If Littermates Were Uncorrelated	Differences
Both herniated	6	$p^2n=$ 1.5	4.5
One herniated	39	$2pqn=$ 48.0	—9
Neither herniated	369	$q^2n=364.5$	4.5

The tetrachoric correlation was 0.19 for these litters of two. Perfect correlation would exist only if all litters were either wholly herniated or lacked hernia completely. Naturally such a perfect correlation never occurs, but the correlations found between litter mates show that there is a real excess of litters free of hernia and of litters with more than a random share of hernia.

Breeding Plan

The rate of genetic improvement that could be expected under the different methods of selection can be calculated following the procedure outlined by Lush (1947). Combination selection is

$$\sqrt{1+\frac{(r-t)^2\,(n-1)}{(1-t)\quad[1+(n-1)t]}}$$

times as effective as mass (individual) selection. This is completely determined by r, the correlation between breeding values of members of a family; t, the phenotypic correlation between members of a family; and n, the number of individuals in the family.

In a population of inbred lines one might select among the lines. When the individuals in a line have an average F of 0.28 and the average F of their offspring is 0.30, the average genetic correlation between line mates is:

$$r=\frac{2\ (.30)}{\sqrt{(1.28)}\ \sqrt{(1.28)}}=0.469$$

The phenotypic correlation between individuals in a line is:

$$t=\frac{\sigma T^2}{\sigma B^2+\sigma S^2+\sigma T^2+\sigma E^2}=0.035$$

The average number of boar pigs born in a line per season in this herd has been sixteen. Therefore, the relative value of combination selection as compared with individual selection is:

$$\sqrt{1+\frac{(.434)^2}{.965}\cdot\frac{15}{1+15(.035)}}=1.7$$

This indicates that selection on the basis of the best combination of attention to line average and to individual phenotype is about 1.7 times as effective as selection on individual phenotype. However, it will take several generations to form these inbred lines. Therefore, on a per generation basis utilizing line differences will not have as large an advantage over mass selection as this appears.

By selecting against the dams which have produced herniated pigs, a breeder would effectively lower the incidence of hernia if the maternal effect is completely genetic. How much of the maternal effect is genetic was not determined in this study, but is definitely needed to determine the effect of selecting against dams of herniated pigs.

Summary

Over the last ten years approximately 5 percent of the male pigs weaned in this herd have had scrotal hernia.

The differences between lines are greater than could be explained by chance alone. These differencs have fluctuated from year to year, but little if any more than would be expected by chance.

The yearly differences in the incidence of scrotal hernia were not statistically significant.

The estimates of heritability for scrotal hernia were about 0.15 when based on differences among sires within lines. A less dependable esti-

mate, based on differences among lines, was about 0.07. These figures estimate the amount to which the additive effects of his genes determine whether a male pig which reaches weaning age had scrotal hernia or not.

Whether or not a male pig had scrotal hernia was also 15 percent determined by a maternal effect. It was not determined to what extent this unexpectedly large maternal effect was genetic or environmental.

The large maternal effect indicates that a breeder should practice strong selection against sows that have produced herniated pigs. If the maternal effect can be identified as some environmental effect and if the environment which causes hernia can be easily corrected, that would offer a way to lower the incidence of hernia.

Since scrotal hernia is a threshold characteristic with low heritability, hernia could be reduced by forming many inbred lines, selecting those which have the least hernia and crossing them together to form new lines. Scrotal hernia is not important enough by itself to warrant forming inbred lines but, since many lines are being formed for other reasons, the incidence of hernia should be considered when selecting among the lines.

Literature Cited

Henderson, C. R. 1948. Variance components. Lecture Series, Animal Breeding Subsection. Iowa State College, Ames. Ia.

Lush, J. L. 1947. Family merit and individual merit as bases for selection. Amer. Nat. 81:241, 362.

Lush, J. L., W. F. Lamoreux, and L. N. Hazel, 1948. The heritability of resistance to death in the fowl. Poul. Sci. 27:375.

Warwick, B. L. 1926. A study of hernia in swine. Wisc. Agr. Exp. Sta. Res. Bul. 69:1.

Warwick, B. L. 1931. Breeding experiments with sheep and swine. Ohio Agr. Exp. Sta. Bul. 480:25.

THE EFFECT OF SUMMER ENVIRONMENT ON THE BODY TEMPERATURE AND RESPIRATION RATE OF SWINE

A. L. TIDWELL[1] AND J. L. FLETCHER
Mississippi State College

SEVERAL studies have been conducted to determine the optimum atmospheric temperature and relative humidity for most rapid and economical gains in swine. In several of these studies body temperature and respiration rate have also been used to measure the effect of these environmental factors. In most instances these tests have been conducted under laboratory conditions which did not permit exposure to the sun. In the present study exposure to summer sun was provided simultaneously with naturally occurring variations in atmospheric temperature and relative humidity.

Heitman and Hughes (1949) reported that as the air temperature increased above 40° F. the respiration rate and body temperature increased. This rise was less in light weight pigs than in heavy pigs. It was also reported that increasing the relative humidity from 30 to 90 percent had little effect upon body temperature but did cause an increase in respiration rate. In an earlier report, Palmer (1917) stated that the direct rays of the sun caused a marked increase in the body temperature. Temperatures as high as 108° F. were observed. Fletcher (1949) reported that during a 15 minute exposure to sunlight at an air temperature of 88.3° F. the body temperature of market weight barrows rose 1.16° F.

Heitman and Hughes (1949) stated that pigs weighing 166 to 260 pounds gained more rapidly and consumed less feed per pound of gain when the air temperature was near 60° F. while pigs weighing between 70 and 144 pounds were most efficient at 75° F. Deighton (1929) noted that at 61° F. Berkshire pigs could be maintained with less feed than could Medium or Large White pigs.

A lack of skin moisture was suggested by Brody (1945) as probable cause for over-heating in non-sweating animals such as the pig. In non-sweating animals there could be little cooling by vaporization of moisture from the body surface. According to Brody, it was logical for the pig to wallow in an effort to increase surface moisture for vaporiza-

[1] This study was conducted in partial fulfillment of the requirements for the degree of Master of Science in Animal Husbandry.

tion. The body temperature of pigs in pastures without wallows was reported by Bray and Singletary (1948) to be as high as 106° F. on hot days. At the same time pigs having access to wallows were found to have body temperatures between 102° F. and 104° F. It has also been reported by Jackson (1938) that hogs having access to wallows gained more rapidly and were more efficient than similar pigs without access to wallows.

Methods and Experimental Procedure

In the present study eight pigs with initial weights ranging from 116 to 183 pounds were used as experimental animals. These eight pigs included two Duroc barrows, two Duroc gilts, two Poland China barrows, and two Poland China gilts.

Throughout the entire experimental period all pigs were hand fed shelled corn and a protein supplement composed of equal parts of tankage, soybean meal, and alfalfa meal. The daily ration was fed in two feedings, one in the morning and one in the late afternoon.

The pigs were maintained in pens located in the main farrowing house. In these pens the pigs had access to outside concrete runways.

During June and July data were secured on all of these pigs on 10 suitable test days. Days considered suitable were those days on which atmospheric temperature inside the farrowing house reached or exceeded 80° F. at 2:00 P.M. and relatively clear skies prevailed.

On test days the pigs were confined to the shade of the barn between 9:00 A.M. and 2:00 P.M. At 2:00 P.M. atmospheric temperature and relative humidity in the farrowing house were determined and recorded. Relative humidity was determined by means of a sling psychrometer. As soon as environmental conditions had been determined the body temperature and respiration rate was determined on each pig. Respiration rate was determined by counting the flank movements of the pig and body temperature by use of a rectal thermometer. Respiration rate and temperature were secured with the least possible amount of agitation of the pigs. Following determination of the temperature and respiration rate the pigs were driven into the outside runway. In the outside runway which was on the west side of the farrowing house, no shade or water was provided.

On alternate test days the pigs were kept in the outside runways for 15 minutes and 30 minutes respectively. At the end of each exposure period the pigs were returned to the inside of the house and rectal temperature and rate of respiration determined.

Results

In table 1 are shown the air temperature and relative humidity on the days the pigs were exposed to the sun for 15 minutes. The average body temperature and the average body temperature-change that occurred during each day are recorded. Data in table 1 indicate that there was no correlation between air temperature or relative humidity and the initial body temperature of the pigs. Statistical test as outlined by Snedecor (1946) verified this observation.

TABLE 1. AVERAGE INITIAL BODY TEMPERATURE AND CHANGES IN BODY TEMPERATURE ON DAYS EXPOSED TO SUN FOR 15 MINUTES

Date	Air Temperature	Relative Humidity	Initial Body Temperature	Body Temperature Rise
	°F	%	°F	°F
June 29	90	61	102.37	1.23±.20[1]
July 6	91	58	101.47	1.19±.12
July 14	85	73	102.22	0.55±.15
July 17	82	80	101.57	0.50±.12
July 19	90	55	101.70	1.25±.15
Average	87.6	65.4	101.86	0.94±.25

[1] Standard error.

The differences in body temperature rise on different days as shown in table 1 were statistically significant. There was a highly significant positive correlation between air temperature and increase in body temperature during 15-minute exposure. A reverse relationship existed between humidity and initial body temperature change. A significant negative correlation existed between relative humidity and body temperature change.

The effect of 30-minute exposure on body temperature is shown in table 2. On the days these observations were made the air temperature ranged from 86° F. to 91° F. and the relative humidity ranged from 58 to 76 percent. The average air temperature and relative humidity on these five days were approximately the same as the average on the five days of the 15-minute exposure. There was not a significant correlation between air temperature or relative humidity and the change in body temperature. However, the correlation between air temperature and body temperature-rise did approach significance. The average rise in body temperature of all pigs during a 30-minute exposure as shown

TABLE 2. AVERAGE INITIAL BODY TEMPERATURE AND CHANGES IN BODY TEMPERATURE ON DAYS EXPOSED TO SUN FOR 30 MINUTES

Date	Air Temperature	Relative Humidity	Initial Body Temperature	Body Temperature Rise
	°F	%	°F	°F
June 28	90	58	102.66	1.87±.22
July 1	88	67	102.13	1.77±.16
July 11	91	62	101.82	2.63±.24
July 15	88	64	101.90	2.10±.15
July 18	86	76	101.67	1.50±.18
Average	88.6	65.4	102.03	1.97±.37

in table 2 was significantly greater than the rise on days exposed for 15 minutes as shown in table 1. The average rise in body temperature of all pigs on all days of 30-minute exposure was more than 100 percent greater than the average rise during a 15-minute exposure.

The air temperature, relative humidity and respiration rate averages on days of 15-minute exposure are found in table 3. The average initial respiration rate for all pigs on all days was increased 100 percent when the pigs were exposed for 15 minutes. An air temperature of 85° F. and a relative humidity of 73 percent caused the least respiration increase. This difference between days in the average increase in respiration rate was highly significant.

In table 4 are noted the air temperatures and relative humidities on days of 30-minute exposure. Table 4 also shows the initial respiration

TABLE 3. AVERAGE INITIAL RESPIRATION RATE AND CHANGES WHEN EXPOSED TO SUN FOR 15 MINUTES

Date	Air Temperature	Relative Humidity	Initial Respiration Rate	Respiration Rate Rise
	°F	%	Per Minute	Per Minute
June 29	90	61	62.3	40.9± 8.4
July 6	91	58	73.0	51.1± 8.6
July 14	85	73	45.8	39.3±11.1
July 17	82	80	21.7	40.1± 8.8
July 19	90	55	42.5	77.6±18.5
Average	87.6	65.5	49.8	49.8±10.9

rates per minute and the respiration changes on the different days. The average initial respiration rate increased 150 percent during 30-minutes exposure. The average air temperature and relative humidity on these days were 88.6° F. and 65.4 percent, respectively.

The difference in increase in respiration rate on different days was statistically significant. The differences in increase in respiration rate when exposed for 15 and 30 minutes were highly significant. As has been shown in table 3 the average rise in respiration that followed a 15-minute exposure was 49.8 respirations per minute. Table 4 shows that the average rise in respiration that occurred during exposure for

TABLE 4. AVERAGE INITIAL RESPIRATION RATE AND CHANGES WHEN EXPOSED TO SUN FOR 30 MINUTES

Date	Air Temperature	Relative Humidity	Initial Respiration Rate	Respiration Rate Rise
	°F	%	Per Minute	Per Minute
June 28	90	58	78.8	60.5±12.3
July 1	88	67	56.8	66.5± 6.6
July 11	91	62	60.8	100.0± 4.9
July 15	88	64	42.3	99.0± 9.0
July 18	86	76	30.6	78.4±10.8
Average	88.6	65.4	53.7	80.8±15.5

30 minutes was 80.8. Exposure for 30 minutes increased the respiration rate approximately 30 respirations more per minute than the 15-minute exposure.

In table 5 are noted the average body temperature and respiration rate increases for 15 and 30-minute exposures of all individual pigs. It will be observed that an exposure of 15 minutes resulted in an average increase in body temperature of 0.92° F. The differences between individuals in temperature rise during the 15-minute exposure were not statistically significant. The average increase in respiration rate during the 15-minute exposure was 49.6 respirations per minute. The differences between individuals in respiration rise in this exposure period was significant. In addition a significant difference existed between the average rise of 36.4 respirations for the Duroc pigs and the average rise of 61.6 respirations for the Poland pigs. A significant positive correlation was found to exist between the temperature increase and respiration increase during this 15-minute exposure.

As shown in table 5 the average rise in temperature during the 30-minute exposure period was 1.94° F. This increase in body temperature was significantly greater than the rise of 0.92° F. which occurred during the 15-minute exposure. Again it was found that the differences between individuals in temperature rise were not significant. The 0.29° F. greater rise in temperature of the Poland pigs during the 30-minute exposure was significant statistically. As in the case of the 15-minute exposure there were differences between individuals in the amount of respiration rate changes when the pigs were exposed for 30 minutes.

TABLE 5. AVERAGE BODY TEMPERATURE AND RESPIRATION RATE INCREASES DURING 15- AND 30-MINUTE EXPOSURES

Pig Number	15-Minute Exposure		30-Minute Exposure	
	Body Temperature Change	Respiration Rate Change	Body Temperature Change	Respiration Rate Change
	°F.	Per Minute	°F.	Per Minute
DB 0	0.69 ± .30	51.4 ± 20.1	1.84 ± .25	89.8 ± 7.0
DB 110	0.68 ± .18	25.8 ± 7.9	1.72 ± .27	71.0 ± 7.8
DS 0	0.80 ± .28	33.8 ± 3.2	2.04 ± .40	81.6 ± 4.6
DS 103	0.72 ± .19	39.8 ± 10.3	1.50 ± .40	65.0 ± 18.8
Average of Durocs	0.72 ± .03	36.4 ± 5.2	1.80 ± .11	76.4 ± 5.5
PB 34S	1.06 ± .38	66.2 ± 13.8	1.74 ± .26	99.0 ± 12.0
PB 34	1.18 ± .23	65.0 ± 21.4	2.10 ± .41	77.4 ± 22.0
PS 332	0.94 ± .31	44.2 ± 12.6	2.38 ± .31	76.6 ± 20.9
PS 128	1.36 ± .32	71.2 ± 17.5	2.14 ± .18	88.2 ± 4.9
Average of Polands	1.13 ± .08	61.6 ± 6.0	2.09 ± .13	84.9 ± 5.2
Average of all pigs	0.92 ± .09	49.6 ± 5.8	1.94 ± .10	81.0 ± 1.3

Again these differences were statistically significant. Also the increase in respiration rate of the Poland pigs was significantly greater than the increase of the Durocs. In the case of the 30-minute exposure there was not a significant correlation between temperature and respiration rate changes.

The data in table 5 were further analyzed to determine whether differences between sexes were present. There were no significant differences between the sexes in either temperature or respiration response.

Discussion

In this study no correlation was found to exist between air temperature and initial body temperature or relative humidity and initial body temperature. These results are in disagreement with the results reported by Heitman and Hughes (1949). The results reported by these

workers showed that a rising air temperature and rising relative humidity caused a rise in body temperature and respiration. In their study pigs were subjected to a wider range of these two factors than in the present study.

Even though there was no correlation between air temperature or relative humidity and initial body temperature, a combination of air temperature, relative humidity and exposure to sunlight did cause significant increases in initial body temperature and respiration rate. These results are in agreement with those reported by Fletcher (1949) and the observations of Palmer (1917). Under approximately equal conditions of air temperature and relative humidity exposure to summer sun for 15 and 30-minute periods elevated the initial body temperature 0.94° F. and 1.97° F. respectively. It appears that on exposure the effect of sunlight was sufficient to exceed the cooling ability of the pigs.

The body-temperature responses of the individual pigs to a combination of air temperature, relative humidity and exposure for 15 or 30 minutes were not significantly different. It is suggested that this similarity between the pigs was possibly due to the narrow range of temperatures and humidities and the short length of exposure. It is considered possible that all the pigs were capable of eliminating heat at a sufficiently rapid rate to prevent appreciable variation.

There was no correlation between air temperature or relative humidity and body temperature rise when exposed for 30 minutes. This was in contrast to the observed correlations between these factors when the exposure period was 15 minutes. It is suggested that during 30-minute exposure the air temperature and humidity became minor factors in the total temperature rise. Thus the correlation which was observed on 15-minute exposure was obscured by the effect of a longer exposure period.

The two breeds showed significant differences in body temperature rise for both 15 and 30-minute exposures. These differences between the two breeds might have been due to the difference in coat color as was suggested by Lee and Phillips (1948) or to handling as suggested by Palmer (1917). It was observed that the Duroc pigs were more docile than the Poland pigs, and this condition prevailed throughout the experiment.

There was no significant difference between the sexes in increased body temperature following exposure. This was true regardless of breed or length of exposure.

The variation of air temperature and relative humidity coupled with 15 and 30-minute exposures on different days produced variable

respiration rate rises. The higher respiration rate on days of 15 and 30-minute exposures usually occurred on days of highest air temperature and lowest percent of relative humidity. The lower respiration rate on days of 15 and 30-minute exposures usually occurred on days of lowest air temperature and highest relative humidity. It is possible that this condition would not have prevailed had data been taken on a greater number of days and a wider range in air temperature and relative humidity.

The differences in respiration rates following 15 and 30-minute exposure show that exposure to sun was an important factor in the comfort of the pigs. As has already been mentioned the total temperature rise during a 30-minute exposure was proportionately greater than for a 15-minute exposure.

The individuals differed significantly in respiration rate change. This suggests that individuals differ in their ability to cope with factors which tend to increase body temperature. In order to maintain the same body temperature certain individuals were forced to increase respiration significantly more than others.

A positive correlation was found to exist between the respiration rate increase and body temperature rise when exposed for 15 minutes. This correlation did not prevail between respiration rate increase and body temperature rise when exposed for 30 minutes.

The temperature rise during 30-minute exposure was more than twice as great as the rise during 15-minute exposure. The respiration rate increase during 30-minute exposure was less than twice as great as the increase during 15-minute exposure. This suggests that a maximum respiration rate might have been attained before the end of the 30-minute exposure. At the same time body temperature continued to rise. This could account for the lack of correlation between respiration rate increase and body temperature rise during the 30-minute exposure.

Summary

Eight pigs weighing from 116 to 183 pounds were used in this study of the effect of exposure to sunlight. Four pigs were of the Poland breed and four pigs were of the Duroc breed. They were divided equally as to sex. These pigs were exposed to sunlight for 15 and 30 minutes on alternate test days. The exposures were made under naturally occurring air temperature and humidity conditions.

This study showed that there was no correlation between air

temperature or relative humidity and initial body temperature of the pigs.

The differences in body temperature rise on different days of 15-minute exposure were statistically significant. The differences in body temperature rise on different days of 30-minute exposure were also statistically significant. The body temperature rise on 30-minute exposure was significantly greater than the rise on 15-minute exposure. The average rise in body temperature for a 15-minute exposure was 0.92° F. and for a 30-minute exposure 1.97° F.

The differences between individuals in body-temperature rise during 15 or 30-minute exposures were not statistically significant.

The average rise in body temperature of the Poland pigs for both 15 and 30-minute exposures was significantly higher than for the Duroc pigs. The Poland pigs showed an average rise of 1.13° F. for the 15-minute exposure and 2.09° F. for the 30-minute exposure. The average temperature rises for the Durocs during 15 and 30-minute exposure were 0.72° F. and 1.80° F., respectively.

The differences in respiration-rate increase on different days were found to be highly significant.

Differences between the breeds in respiration-rate rise were found to exist when exposed for 15 or 30 minutes. This difference between the two breeds was highly significant. During the 15-minute exposure the average respiration-rate rise for Polands was 25.2 respirations greater than the average respiration-rate rise for Durocs. The difference between the pigs of these two breeds was somewhat less during the 30-minute exposure. During the 30-minute exposure the respiration rate rise for the Polands was only 8.5 respirations per minute higher than for the Durocs.

Individuals within the two breeds showed variable changes in respiration-rate rise. These individual differences were highly significant.

The average rise in respiration for the 15-minute exposure was 49.8 respirations and for the 30-minute exposure 80.8 respirations.

No significant difference was found to exist between the sexes in respiration-rate rise.

A significant positive correlation existed between the body temperature and respiration rate rises during the 15-minute exposure. The average temperature rise was 0.92° F. and the average respiration-rate rise was 49.6 respirations per minute. However, during the 30-minute exposure there was not a significant correlation between temperature and respiration rate rise. The average temperature and respiration rate

rises for 30-minute exposure were 1.94° F. and 81 respirations per minute.

Literature Cited

Bray, C. I. and C. B. Singletary. 1948. Effect of hog wallows on gains of fattening swine. JOURNAL OF ANIMAL SCIENCE. 7:521.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Pub. Corp. N. Y., N. Y. pp. 298–299.

Deighton, Thomas. 1929. A study of the metabolism of two breeds of pigs. Jour. Agr. Sci. 19:141.

Fletcher, J. L. 1949. The effect of exposure to summer sun on the body temperature of market weight barrows. Proc. of the Assn. of Southern Agr. Workers. 1949. pp. 73. (Abstract).

Heitman, H. Jr. and E. H. Hughes. 1949. The effect of air temperature and relative humidity on the physiological well being of swine. JOURNAL OF ANIMAL SCIENCE 8:171.

Jackson, A. D. 1938. Fattening hogs need concrete wallows in hot weather. Progress Report, Texas Agr. Expt. Sta., Texas A. & M. College.

Lee, D. H. K. and R. W. Phillips. 1948. Assessment of the adaptability of livestock to climatic stress. JOURNAL OF ANIMAL SCIENCE 7:391.

Palmer, C. C. 1917. The effect of muscular exercise and the heat of the sun on the blood and body temperature of normal pigs. Jour. Agr. Res. 19:167.

Snedecor, G. W. 1946. Statistical methods. Fourth Edition. The Iowa State College Press. Ames, Iowa.

SEASONAL VARIATION IN THE FAT, VITAMIN A, AND VITAMIN D CONTENT OF SOW'S COLOSTRUM AND MILK[1]

J. P. BOWLAND,[2] R. H. GRUMMER, P. H. PHILLIPS, AND G. BOHSTEDT[3]
University of Wisconsin[4]

INCREASED interest in the preparation of synthetic milk, as well as realization of the importance of colostrum and milk in the nutrition of the newborn, has hastened a renewed study of the milk of domestic animals other than the cow. Hughes and Hart (1935) reviewed the early literature on the gross composition of sow's milk. The literature on the fat and vitamin A levels in sow's milk has been reviewed by Bowland *et al.* (1949a). Prior to that publication, Braude *et al.* (1947) (1946) had published the most comprehensive studies of sow's milk. They found that a pooled sample of sow's milk fat taken between July and December had a potency of 0.55 I.U. vitamin D per gm. which was within the range observed in cow's milk. Luecke *et al.* (1947) made determinations of vitamin A in sow's colostrum.

In recent months several reports have appeared dealing with factors which affect the composition of sow's milk. Heidebrecht *et al.* (1948) presented data on the effect of stage of lactation on the composition of milk from swine fed a corn-soybean oil meal ration. Fat content averaged from 9.00 percent on the fifth day to 7.15 percent on the fifty-fifth day of lactation, while vitamin A averaged from 112.60 γ per 100 ml. of colostrum to 14.10 γ per 100 ml. of milk on the fifty-fifth day.

Thomas *et al.* (1947) and Whiting *et al.* (1949) were able to increase the average vitamin A content of samples of colostrum from sows by feeding vitamin A supplements. For unsupplemented rations the former authors reported an average of 169 γ vitamin A per 100 ml., and the latter reported an average of 24 γ of vitamin A per gm. of fat.

Procedure

This experiment was designed to study seasonal variation in the fat, vitamin A, and vitamin D content of sow's colostrum and milk.

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station, Madison.
[2] Present address—Department of Animal Science, University of Alberta, Edmonton.
[3] The authors wish to acknowledge the assistance of Dr. H. T. Scott, Director of Biological Research, Wisconsin Alumni Research Foundation, for conducting the vitamin D assays.
[4] Departments of Animal Husbandry and Biochemistry, Madison, Wisconsin.

Forty-eight crossbred Poland China-Hampshire gilts, 8 weeks of age, were divided into 3 lots on April 20. Lot 1 was placed in dry lot and self-fed a ration of 75.1 percent ground yellow corn, 9.0 percent soybean oil meal, 6.0 percent tankage, 4.5 percent gluten meal, 5.0 percent ground dehydrated alfalfa meal, 0.9 percent ground limestone, and 0.5 percent iodized salt. Lots 2 and 3 were placed on pasture and were self-fed the same basal ration as lot 1. One half of the gilts in each of the 3 lots (group A) were bred between September 20 and October 10. With the onset of cold weather in mid-November, lots 2 and 3 were transferred to dry lot. Lot 2 was continued on the same basal ration, while lot 3 had 25 percent of ground dehydrated alfalfa meal incorporated into the ration with the other constituents being altered to maintain a similar nutritive ratio. The second half of the gilts in each lot (B groups) were bred between December 13 and January 7.

The sows were milked immediately after parturition and at the end of the first, the fourth and the eighth weeks of lactation. The oxytocic hormone (Pitocin from Parke, Davis and Co.) was used to stimulate milk letdown as described by Bowland *et al.* (1949). Fat and vitamin A analyses were run on all samples. Fat was determined by means of the Minnesota Babcock reagent, while vitamin A was determined by the method of Boyer *et al.* (1944). Composite samples of milk on the twenty-first day of lactation were taken from each lot and assayed for vitamin D by the line test in rats (U.S.P. 1947). A sample of milk taken from sows on pasture in August was also assayed for vitamin D.

Results and Discussion

Nutritional inadequacies of the basal ration apparently accounted for poor reproductive performance in the sows kept continuously on dry lot. Pigs from 4 of the 6 sows which farrowed in lots 1A and 1B had congenital malformations and deformities similar to those observed by Ross *et al.* (1944). Because of this poor performance studies could be made on only one sow in each of groups 1A and 1B for the entire lactation.

Table 1 shows results of the fat and vitamin A analysis according to treatment and season. The fat content of the milk was very similar for sows from the various lots and groups except that the fat in the colostrum from the lot 1 sows was found to be considerably lower than that in the colostrum of the lot 2 and 3 sows. The lot 1 sows were in a noticeably thinner condition than the sows in the other two lots

which may have caused the difference in initial outpour of fat into the colostrum.

Both treatment and season appeared to have some effect on the vitamin A content of the milk fat. Lot 1 sows that were kept on continuous dry lot had lower vitamin A values than did the sows that

TABLE 1. THE LACTATION TREND IN THE COMPOSITION OF WINTER AND SPRING COLOSTRUM AND MILK

Milk constituent	Lot no.	Group	No. of sows	Colostrum	Milk			
				1 day	1 wk.	4 wk.	8 wk.	Av. 1–8 wk.
Fat %	1	A	1[1]	3.13	13.39	6.66	8.50	8.28
		B	1[2]	3.95	10.17	9.72	5.76	8.55
	2	A	7	5.58	8.03	8.16	9.20	8.46
		B	5[3]	5.40	9.35	8.57	6.54	8.35
	3	A	4[4]	5.15	8.04	8.55	6.60	7.73
		B	9	6.22	8.86	8.14	6.21	7.97
Vitamin A γ/gm. of fat	1	A	1[1]	29.5	5.0	5.6	2.8	4.2
		B	1[2]	18.8	3.0	2.1	4.6	3.2
	2	A	7	22.0	8.6	7.2	4.4	6.7
		B	5[3]	23.3	4.3	3.4	4.5	4.1
	3	A	4[4]	26.4	9.6	5.7	8.1	7.8
		B	9	19.9	5.0	3.0	5.2	4.6

[1] Three sows are included in the 1-day and 1-week averages.
[2] Three sows are included in the 1-day averages.
[3] Six sows are included in the 1-day averages.
[4] Five sows are included in the 1-day averages.

had access to pasture. In turn, the milk fat from the lot 3 sows contained slightly more A than that shown by the sows in lot 2. If this is a real difference it might be explained on the basis of dietary intake of vitamin A precursors during the post-pasture season (25% as compared to 5% dehydrated alfalfa in the ration). In each lot the group B sows (spring farrow) showed lower average vitamin A values than did the sows that farrowed during the winter, a weighted mean of 4.4 γ/gm. fat compared to 7.0 γ. Depletion of body vitamin A stores may have accounted for this seasonal variation.

TABLE 2. VITAMIN D CONTENT OF SOW'S MILK

Ration	Date sampled	Period in lactation	% Fat	Vitamin D	
				I.U./quart	I.U./gm. of fat
Pasture	Aug. 6, 1948	14–21 days	8.5	150–175	1.86–2.18
Lot 1A	Feb. 18, 1949	21 days	7.7	115–125	1.58–1.71
Lot 2A	Feb. 3, 1949	21 days	7.5	>100	>1.41
Lot 3A	Feb. 3, 1949	21 days	10.4	115–125	1.17–1.27
Lot 1B	Apr. 28, 1949	21 days	5.8	100	1.83
Lot 2B	Apr. 28, 1949	21 days	5.2	<50	<1.02
Lot 3B	Apr. 28, 1949	21 days	5.8	80–90	1.47–1.64

The vitamin D content obtained in assays of 7 composite samples of sow's milk is outlined in table 2. Summer milk from sows on pasture was slightly higher in vitamin D content than was either winter or spring milk. However, milk from sows in February was still high indicating considerable ability of the sow to store vitamin D. The April milk was somewhat lower in vitamin D on a unit of volume basis, although the concentration was quite high per unit of fat.

Because of the small numbers of animals used in this study any difference between treatments and season must be considered as trends rather than real differences.

Table 3 gives a day-by-day fat and vitamin A analysis on the milk of 2 sows for the first week of lactation. Colostrum was low in fat, but after the first day the fat content rose rapidly and leveled off after the third day. On the other hand, colostrum was high in vitamin A. By the second day the A concentration dropped sharply and leveled after the fourth day.

TABLE 3. LACTATION TREND IN THE COMPOSITION OF SOW'S MILK DURING THE FIRST WEEK[1]

Milk constituent	Period in lactation						
	1 day	2 day	3 day	4 day	5 day	6 day	7 day
Fat %	3.87	11.38	10.39	8.05	8.19	8.82	9.42
Vitamin A γ/gm. of fat	25.0	14.4	12.5	8.4	7.4	6.6	7.1

[1] Data from 2 sows in lot 2A.

Summary

Pregestation intake of vitamin A percursors influences the A content in sow's milk. The vitamin A and D values in the milk of sows farrowing in February as compared with sows farrowing in April suggest a gradual depletion in the body stores of these two vitamins. Condition of a sow at the time of parturition influences the concentration of fat in the sow's colostrum.

Literature Cited

Bowland, J. P., R. H. Grummer, P. H. Phillips and G. Bohstedt. 1949. The vitamin A and vitamin C content of sows' colostrum and milk. JOURNAL OF ANIMAL SCIENCE 8:98.

Bowland, J. P., R. H. Grummer, P. H. Phillips and G. Bohstedt. 1949a. Effect of lactation and ration on the fat and vitamin A level of sow's milk. Jour. Dairy Sci. 32:22.

Boyer, P. D., R. Spitzer, C. Jensen and P. H. Phillips. 1944. Determination of vitamin A and carotene in milk. A rapid extraction procedure. Ind. Eng. Chem., Anal. Ed., 16:101.

Braude, R., M. E. Coates, K. M. Henry, S. K. Kon, S. J. Rowland, S. Y. Thompson and D. M. Walker. 1947. A study of the composition of sow's milk. Brit. Jour. Nutr. 1:64.

Braude, R., S. K. Kon and S. Y. Thompson. 1946. A note on certain vitamins of sow's colostrum. Jour. Dairy Res. 14:414.

Heidebrecht, A. A., O. B. Ross, R. W. MacVicar and C. K. Whitehair. 1948. Reproduction and lactation studies of swine fed corn-soybean oil meal rations. JOURNAL OF ANIMAL SCIENCE 7:528, and mimeographed material presented at the 1948 American Society of Animal Production Meetings, Chicago.

Hughes, E. H. and G. H. Hart. 1935. Production and composition of sow's milk. Jour. Nutr. 9:311.

Luecke, R. W., C. W. Duncan and R. E. Ely. 1947. Milk studies. I. Some vitamin and trace elements found in the colostrum of the dairy cow, beef cow, and swine. Arch. Biochem. 13:277.

Ross, O. B., P. H. Phillips, G. Bohstedt and T. J. Cunha. 1944. Congenital malformations, syndactylism, talipes and paralysis agitans of nutritional origin in swine. JOURNAL OF ANIMAL SCIENCE 3:406.

The Pharmacopoeia of the U.S.A. or the U. S. Pharmacopoeia. 1947. XIII:723.

Thomas, J. W., J. K. Loosli and J. P. Willman. 1947. Placental and mammary transfer of vitamin A in swine and goats as affected by the prepartum diet. JOURNAL OF ANIMAL SCIENCE 6:141.

Whiting, F., J. K. Loosli and J. P. Willman. 1949. The influence of tocopherols upon the mammary and placental transfer of vitamin A in the sheep, goat and pig. JOURNAL OF ANIMAL SCIENCE 8:35.

THE GROWTH PROMOTING EFFECTS OF VARIOUS ANTIBIOTICS ON PIGS[1]

R. W. Luecke, F. Thorp, Jr., H. W. Newland and W. N. McMillen[2]

Michigan Agricultural Experiment Station

USING a purified diet, the requirement of the pig for crystalline vitamin B_{12} has been demonstrated by Anderson and Hogan (1950) and Neumann *et al.* (1950). Nesheim *et al.* (1950) have found the oral vitamin B_{12} requirement of the baby pig, fed a purified diet, to be approximately 9 μg. per pound of dry matter consumed.

Recently the growth-promoting effects of aureomycin and streptomycin for pigs have been found by Jukes *et al.* (1950) and Luecke *et al.* (1950). In the latter paper it was reported that the inclusion of streptomycin in a corn-soybean ration at a level of 225 mg. per pound of feed resulted in a 40 percent increase in growth over the control group. In view of the fact that a high level of streptomycin gives a pronounced stimulation in growth it seemed advisable to determine whether lower levels of the same antibiotic would also stimulate growth. In addition it seemed to be of interest to determine whether the presence or absence of niacin, calcium pantothenate, riboflavin and vitamin B_{12} would have any effect on the growth stimulating properties of streptomycin. Therefore, this paper will be concerned with the effect of various B vitamins on the growth-promoting properties of streptomycin on pigs, and also a study of the growth-promoting effects of aureomycin, penicillin and neomycin.

Experimental

The pigs used in the experiment were Durocs, approximately 7 weeks of age when placed on the trial. The two rations used are shown in table 1. The protein contents of rations A and B were 18.1 and 18.3% respectively. A vitamin A and D concentrate (Quadrex) was added to both rations in amounts which supplied 2000 I.U.

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station as Journal Article No. 1195.

[2] Departments of Agricultural Chemistry, Animal Pathology and Animal Husbandry, Michigan State College, East Lansing. The authors are indebted to Merck & Co., Inc., Rahway, New Jersey for B vitamins, streptomycin and procane penicillin; to Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York for B vitamins, aureomycin and APF; and to The Upjohn Co., Kalamazoo, Michigan for neomycin.

TABLE 1. BASAL RATIONS FED IN ANTIBIOTIC TRIAL

Constituents of ration	A	B
Corn	71.5	65.5
Soybean oil meal (solvent)	25.0	17.0
Meat and bone scraps		5.0
Dehydrated alfalfa		5.0
Distillers dried solubles		5.0
Mineral mixture[1]	3.5	2.5

[1] The composition of the mineral mixture was as follows: dicalcium phosphate (Pura-Phos), 37%; limestone, 35%; iodized salt, 25%; trace mineral premix (Cal. Carb. Corp.), 3%.

of vitamin A and 200 I.U. of vitamin D_2 per pound of feed. All of the pigs were kept on concrete floors, bedded with wood shavings, were self-fed and had access to automatic waterers.

Results and Discussion

The growth response of the pigs fed ration A and the various supplements are shown in table 2. The addition of streptomycin at a level of 10 mg. per pound to basal ration A (lot 2) increased growth slightly although this increase was not statistically significant. It must

TABLE 2. RESPONSE OF PIGS FED THE VARIOUS SUPPLEMENTS TO RATION A

(Nine pigs in each lot on trials lasting 12 weeks)

Lot No.	Suppements to Ration A	Initial weight-lb.	Av. daily gain-lb.	Av. daily ration-lb.	lbs. feed/lb. of gain
1	None	26	0.70	2.50	3.57
2	S[1] @ 10 mg./lb.	27	0.84	2.95	3.52
3	B vits.[2]+S @ 10 mg./lb.	26	1.36	4.21	3.10
4	B vits.[2]+B_{12}[3]	26	1.24	3.89	3.14
5	B vits.+B_{12}+S @ 10 mg./lb.	26	1.38	4.26	3.09
6	B vits.+B_{12}+A[4] @ 10 mg./lb.	26	1.50*	4.57	3.05
7	B vits.+B_{12}+N[5] @ 10 mg./lb.	26	0.84	2.61	3.11
8	B vits.+B_{12}+P[6] @ 1 mg./lb.	27	1.48*	4.48	3.03
9	B vits.+B_{12}+P @ 5 mg./lb.	27	1.45*	4.42	3.05
10	B vits.+APF[7] @ 0.35%	26	1.90*	5.81	3.06

* Daily gains significant over lot 4 ($P = 0.05$).

[1] Streptomycin.

[2] B Vitamins: niacin, 15 mg.; calcium pantothenate 10 mg.; riboflavin 2 mg. per lb. of feed.

[3] Crystalline Vitamin B_{12}, 12.5 μg. per lb. of feed.

[4] Aureomycin.

[5] Neomycin.

[6] Procaine penicillin.

[7] A dried product obtained from aureomycin fermentation and containing 6 mg. aureomycin per gm. of dried material as assayed using the organism *Staphylococcus aureus*.

be said, however, that the pigs in lot 1 and 2 were not normal healthy appearing animals during the latter portion of the trial. This is evidenced also by the low average daily gains and the rather poor efficiency of feed utilization. The fact that the pigs in lot 1 grew poorly is not surprising since previous work at the Illinois and Michigan Stations has indicated that rations composed chiefly of corn and soybean meal were inadequate when fed to growing pigs in dry lot (Krider *et al.*, 1948; Luecke *et al.*, 1950). The addition of the three B vitamins and streptomycin (lot 3, table 2) resulted in a significant increase in average daily gain when compared to the daily gain of pigs in lot 1. That this marked increase in body weight gain was due principally to the B vitamins added and not to the streptomycin can be seen by comparing the average daily gains of lots 4 and 5. In comparing the average daily gains of lots 3 and 5 it can be concluded that, under the conditions of the experiment, the addition of vitamin B_{12} did not significantly increase the growth rate. The results obtained with the first 5 lots indicate that each supplement to the corn-soybean meal ration A was specific in action. Feed efficiencies also exhibit the same additive pattern although these differences are less marked.

For purposes of further comparison, the average growth response obtained with the pigs in lot 4 served as controls in judging the growth promoting effects of the other antibiotics studied. The results obtained by adding streptomycin to the fortified ration A (lot 5) indicate that growth was increased somewhat, but the increase was not statistically significant. The addition of aureomycin at 10 mg. per pound of feed proved to be very effective in increasing the average daily gain (lot 6, table 2). Aureomycin would appear to be more effective at this level than streptomycin.

The results obtained with the animals in lot 7 (table 2) indicate that the antibiotic neomycin fed at levels of 10 mg. per pound of feed had a deleterious effect on growth. It is interesting to note that while the pigs in this lot showed a depressed daily gain and feed consumption, the efficiency with which the animals converted feed to body weight gain was good. It is difficult to imagine that palatibility was a factor because of the very small amounts used. However, if one assumes that the growth promoting properties of various antibiotics are due to an altered intestinal microflora, then one might assume further that the addition of neomycin, at this level, altered the intestinal microflora in an unfavorable manner. The results with neomycin raise the question as to whether or not there are other

antibiotics which might have the same deleterious effect. If this is true then caution should be exercised in the indiscriminate use of antibiotic residues in swine feeds.

The addition of procane penicillin to the fortified ration A at levels of 1 and 5 mg. per pound resulted in a significant growth response. It is interesting that penicillin fed at levels of 5 mg. per pound was no more effective than the same antibiotic fed at a level of 1 mg. per pound.

Pigs in lot 10 fed the dried APF supplement, in the amount indicated in table 2, grew at a more rapid rate than animals in any other lot in the experiment. Since this APF supplement contained aureomycin, it seems possible to conclude that the growth promoting properties of this supplement was due, in part at least, to the aureomycin it contained.

TABLE 3. RESPONSE OF PIGS FED RATION B SUPPLEMENTED WITH STREPTOMYCIN AND B VITAMINS
(9 pigs per lot on trials lasting 12 weeks)

Lot. No.	Supplements to Ration B	Initial weight-lb.	Av. daily gain-lb.	Av. daily ration-lb.	lb. feed/lb. of gain
11	None	26	0.88	3.11	3.54
12	S[1] @ 10 mg./lb.	25	1.08	3.51	3.25
13	B vits.[2]+S @ 10 mg./lb.	25	1.39*	4.17	3.00

* Daily gain significant over lot 11 ($P = 0.05$).
[1] Streptomycin.
[2] See footnote 2, table 2.

In view of the results obtained with the addition of streptomycin to the corn-soybean ration A it seemed of interest to determine if the same general results would be obtained with the mixed type ration B (table 1). The results of this trial are shown in table 3. The addition of streptomycin to ration B resulted in an increase in growth, although, as was the case in lots 1 and 2, this increase was not statistically significant. However, in lot 13, the addition of the B vitamin mixture and streptomycin resulted in a significant increase in growth weight, and a marked increase in the efficiency with which the animals converted feed to body weight gain. Again, as in lots 1 through 5 (table 2), the additive nature of the growth response suggests that each supplement was specific in action. These data suggest further that the growth promoting properties of certain antibiotics may be influenced by the fortification of diets with certain B-complex vitamins.

Summary

1. Streptomycin fed at levels of 10 mg. per pound of feed in a corn-soybean and a mixed ration resulted in a small increase in the growth rate of young pigs, but this increase was not statistically significant. However, the addition of liberal quantities of niacin, calcium pantothenate and riboflavin plus the streptomycin increased the growth rate on both rations significantly.

2. Aureomycin fed at levels of 10 mg. per pound of feed increased significantly the growth rate of young pigs fed a B vitamin fortified corn-soybean ration. Procane penicillin was also found to be effective in this respect at levels of 1 and 5 mg. per pound of feed.

3. A dried APF product, containing aureomycin, gave excellent growth when fed at levels of 0.35% in a B vitamin fortified corn-soybean ration.

Literature Cited

Anderson, G. C. and A. G. Hogan. 1950. Requirement of the pig for vitamin B_{12}. Jour. Nutr. 40:243.

Jukes, T. H., E. L. R. Stokstad, R. R. Taylor, T. J. Cunha, H. M. Edwards and G. B. Meadows. 1950. Growth-promoting effect of aureomycin on pigs. Arch. Biochem. 26:324.

Krider, J. L., D. E. Becker, R. F. VanPoucke and M. E. James. 1948. Crystalline or crude concentrates of B-vitamins supplement a corn-soybean meal ration for weanling pigs in drylot. JOURNAL OF ANIMAL SCIENCE 7:501.

Luecke, R. W., W. N. McMillen and F. Thorp, Jr. 1950. Further studies of pantothenic acid deficiency in weanling pigs. JOURNAL OF ANIMAL SCIENCE 9:78.

Luecke, R. W., W. N. McMillen and F. Thorp, Jr. 1950. The effect of vitamin B_{12}, animal protein factor and streptomycin on the growth of young pigs. Arch. Biochem. 26:326.

Nesheim, R. O., J. L. Krider and B. C. Johnson. 1950. The quantitative crystalline vitamin B_{12} requirement of the baby pig. Arch. Biochem. 27:240.

Neumann, A. L., B. C. Johnson and J. B. Thiersch. 1950. Crystalline vitamin B_{12} in the nutrition of the baby pig. Jour. Nutr. 40:403.

THE EFFECT OF SOFT AND HARD COAL ON THE GROWTH RATE OF PIGS[1]

R. H. GRUMMER, J. H. MEYER, and G. BOHSTEDT
University of Wisconsin[2]

THE feeding of coal to swine is practiced by many farmers. This apparently stems from the fact that pigs like and will consume quantities of coal when it is offered to them. Feeders have been inclined to assume that since pigs liked coal, some constituent in coal was needed by the swine. In spite of the fact that coal is fed, it is surprising that few experiments have been reported on coal feeding. Thompson (1931–32) fed coal as a mineral supplement and found that coal was not as effective as bone meal, limestone, charcoal, or wood ashes.

The following experiments were prompted by the lack of data on the feeding value of coal and the many inquiries received by this station regarding coal feeding.

Experimental

Two feeding trials were conducted in 1948 in which a comparison was made between one lot of pigs fed a basal ration and two lots of pigs fed either soft or hard coal *ad libitum*. The basal ration, fed *ad libitum*, was composed of yellow corn 70, oats 14.5, soybean oil meal 7.5, alfalfa leaf meal 5.0, and tankage 3.0 percent. To check on the desire of the pigs for minerals, limestone and salt were offered free choice. Weanling pigs were used.

The average daily gains were analyzed statistically by the analysis of variance, Snedecor (1946).

Results and Discussion

Because there were no essential differences between the two trials, the combined results are shown in table 1. There were no statistically significant differences between the average daily gains of the three lots.

Daily feed consumption was about the same in each lot. The feed required per 100 pounds of gain was higher for the groups receiving coal. The cost of the feed required for 100 pounds of gain was $10.90, $12.05, and $11.32 for the basal, soft coal, and hard coal

[1] Published with the approval of the Director of the Wisconsin Agricultural Experiment Station.
[2] Department of Animal Husbandry, Madison, Wisconsin.

lots respectively. The higher cost for the coal lots was due to the increased feed requirement and the additional cost of the coal.

There was no great difference in mineral consumption indicating that coal did not replace the minerals. The pigs that received soft and hard coal consumed 0.24 and 0.18 pound per day respectively with most of the coal being consumed during the middle of the growth period. Apparently chewing on something of a crunchy nature was

TABLE 1. THE EFFECT OF SOFT AND HARD COAL ON THE PERFORMANCE OF GROWING AND FATTENING PIGS (SUMMARY OF 2 TRIALS)

Items compared	Lot 1 Basal	Lot 2 Soft coal	Lot 3 Hard coal
Pigs per lot	14	14	14
Experimental period, days	136	145	136
Av. initial wt., lb.,	34	35	34
Av. final wt., lb.	194	189	196
Av. da. gain, lb.	1.18	1.06	1.18
Av. da. feed, lb.:			
Basal ration	4.41	4.32	4.50
Gr. limestone	0.003	Trace	0.002
Salt	0.001	0.003	0.011
Soft coal	...	0.24	...
Hard coal	...	...	0.18
Feed per cwt. gain, lb.	375	432	399

a pleasant diversion for the pigs, but was of no benefit in regard to daily gains or efficiency of feed utilization. At the close of the experiment all animals were slaughtered and examined for roundworm, *Ascaris suis*, infection and all lots were found to be equally infected.

Summary

Soft and hard coal were offered to two lots of pigs fed a well-balanced ration. The hogs ate appreciable amounts of both kinds of coal. The coal did not stimulate growth or have a noticeable mineral-sparing action, but increased the cost of gains.

Literature Cited

Snedecor, G. W. 1946. Statistical methods. Applied to experiments in agriculture and biology. Iowa State College Press, Ames, Iowa.

Thompson, C. P. 1930–32. Comparison of common minerals in swine rations. Okla. Rpt. 1930–32, pp. 67.

VALUE OF COROZO PALM NUT AND SESAME OIL MEALS, BANANAS, A.P.F. AND COW MANURE IN RATIONS FOR GROWING AND FATTENING PIGS[1]

R. L. SQUIBB AND E. SALAZAR[2, 3]
Instituto Agropecuario Nacional

THIS is a preliminary report of a series of studies in the American Tropics on the nutritional value of local feedstuffs for growing and fattening pigs.

Malnutrition in animals is a major problem in these tropical areas. Apparently the problem is related to inadequate storage and transportation facilities, the lack of regulation in feed production, and insufficient experimentation on the nutritional value of indigenous feedstuffs. Many workers have shown that tropical areas contain many valuable feeds that may be used in swine rations (Lewy van Severen, 1949; Munsell *et al.,* 1949; Squibb *et al.,* 1949; Squibb and Wyld, 1949).

The feeds tested in the studies reported herein may be obtained in quantity or may be economically cultivated. Corozo palms (*Orbignya cohune* and species of the genus *Scheelea)* grow abundantly in many areas in the American Tropics. Corozo oil meal, a byproduct of local oil factories, is highly palatable and has been fed to animals for a number of years. Sesame oil meal, which is being produced locally in increased quantities, contains protein of excellent quality and is of value in local chicken rations (Squibb and Wyld, 1948–1949, 1949). Bananas may be obtained readily; large quantities become available as the result of "blow downs" in plantations, rejects for export, or surplus production. Many farms are able to cultivate bananas economically as an animal feedstuff. Bogert, 1942, in a review of the literature, concluded that bananas are nutritious in that they furnish energy, minerals, and certain vitamins. The value of bananas and other tropical fruits and vegetables in rations for swine (at the

[1] A contribution from the Instituto Agropecuario Nacional, a technical agricultural service organization for Guatemala, operated jointly by the Government of Guatemala and by the Office of Foreign Agricultural Relations, U.S.D.A. This study was made possible by funds provided through the U. S. Interdepartmental Committee on Scientific and Cultural Cooperation and funds from the Government of Guatemala.

[2] Animal Husbandmen.

[3] The writers wish to express their appreciation to Mr. Francis Suremain in aiding in the care of the experimental animals and to Dr. T. H. Jukes and the Lederle Laboratories for the APF concentrate.

Hawaiian Experiment Station) has been summarized by Henke, 1949.

The object of the studies reported herein was to evaluate a number of simplified all-vegetable-protein rations for growing and fattening pigs. These rations contained corozo palm nut and sesame oil meals and ripe reject bananas, supplemented with an APF concentrate and cow manure.

Experiments

The experiments reported herein were carried out at the Institute's Chocolá Station, which lies on the slope of a volcano and has an average altitude of approximately 2,700 feet and an average rainfall of 177 inches. Although most of the rain falls during 8 months of the year there is a significant precipitation during the other 4 months.

The pigs used in these experiments were the second and third generation descendants of two purebred Duroc Jersey sows and one purebred Duroc Jersey boar, which had been imported from Minnesota. All pigs were raised on pasture until the start of the trials during which they were kept in concrete pens. The pigs were weighed individually once each week and were fed the experimental rations twice daily in such amounts that there were always small weigh backs. Fresh clean water was constantly available in all pens. All pigs received, in addition to the experimental rations, 0.5 pound of fresh green Kikuyu grass *(Pennisetum clandestinum)* per head per day as a supplemental source of vitamins and other essential nutrients.

Experiment No. 1

The first experiment was begun in February 1949 and was carried on for 110 days. It was designed to test the value of corozo palm nut and sesame oil meals fed separately and in combination as the principal sources of protein.

Eighteen recently weaned Duroc Jersey pigs were divided into three comparable lots of 6 pigs per lot. One of three test rations was randomly assigned to each lot of pigs.

Corozo palm nut oil meal[4] was fed at 30 percent of the concentrate mixture to lot No. 1. The sesame oil meal[5] was added to the ration of lot No. 2 at a level to contribute approximately the same amount of protein as supplied by the corozo oil meal of lot No. 1. For lot No. 3 the corozo and sesame oil meals were added to the ration in such

[4] Corozo oil meal contains: 90.8, dry matter; 19.8, crude protein; 7.2, fat; 36.7, N.F.E.; 4.3, ash; 21.8, crude fiber; 0.14, calcium; and 0.86 phosphorus.

[5] Sesame oil meal contains: 92.2, dry matter; 40.1, crude protein; 14.4, fat; 17.5, N.F.E.; 10.7, ash; 6.0, crude fiber; 2.37, calcium and 1.21, phosphorus.

amounts that each contributed approximately the same amount of protein.

Because corozo oil meal is a medium protein feedstuff, the rations tested contained less protein than recommended for pigs of these ages. Low protein rations are commonly used in this area. The simplified, all-vegetable low protein rations, grouping of the pigs, and the resulting gains are presented in table 1.

As that table indicates, all lots of pigs grew at approximately the same rate. The pigs fed corozo oil meal as the principal source of protein were slightly more efficient in the utilization of feed.

TABLE 1. EFFECT OF COROZO PALM NUT AND SESAME OIL MEALS IN SIMPLIFIED RATIONS FOR GROWING PIGS

Lot No.	No. of pigs	Supplement to basal ration[1]		Total crude protein	Average weight		Average daily gain[2]	Efficiency of gain[3]
					Initial	Final		
			Percent	Percent	Pounds	Pounds	Pounds	
1	6	Corozo meal	30	11.5	40	146	.92	358
2	6	Sesame meal	15	12.6	40	149	.96	376
3	6	Corozo meal	15					
		Sesame meal	7.5	11.9	40	144	.91	370

[1] Consisted of ground yellow corn, 97 percent; calcium carbonate, 1 percent; bonemeal, 1 percent; and iodized salt, 1 percent. The oil meals were substituted for the corn of the basal ration.
[2] No significance between rations in daily gain.
[3] Pounds of feed to produce 100 pounds gain in weight.

Experiment No. 2

Experiment No. 2 was designed to determine the value of ripe bananas (including skins), supplemented with an APF concentrate or dry cow manure, for growing and fattening pigs.

Three test rations were randomly assigned to six lots of pigs, two lots per ration. The rations were fed *ad libitum*. The assignment of the rations, the length of the feeding periods, and other data related to the experiment are presented in table 2. The cow manure supplement was included at 8 percent of the test ration. This supplement was prepared by rapidly-drying the fresh manure in the sun and then grinding it in a hammermill. The APF concentrate was fed at a level equivalent to the APF potency of the cow manure, or 0.7 pound per 100 pounds of the basal concentrate mixture. This potency was determined in the Nutrition Laboratories of the Institute by means of biological assays employing New Hampshire baby chicks. Both the cow manure and the APF concentrate were assayed twice during the trials and once at the end of the trials. The basal concentrate

ration consisted of sesame oil meal, 50; ground yellow corn, 47; calcium carbonate, 1; salt, 1; bonemeal, 1; and Delsterol, 3 grams per 100 pounds of the basal concentrate mix. This ration analyzed 24 percent protein (N×6.25). The cow manure, containing approximately 10 percent protein, and the APF concentrate were substituted for the corn of the basal concentrate mix. In order to regulate the crude protein intake to the weight of the pigs, the basal concentrate mix was fed in a ratio to the ripe bananas. Pigs weighing between 25 and 125 pounds received by weight 1 part of the concentrate mix to 1 part of ripe bananas. This ration analyzed 18 percent protein. Pigs weighing between 125 and 210 pounds received 1 part of the concentrate mix to 2 parts of ripe bananas. This ration analyzed 14 percent protein.

TABLE 2. GROWTH OF PIGS FED RIPE BANANAS AND CONCENTRATES SUPPLEMENTED WITH AN APF CONCENTRATE AND DRY COW MANURE

Lot No.	Supplement to basal ration	No. of pigs	Length of trial	Average weight		Average daily gain	Feed per 100 pounds gain	
				Initial	Final		Concentrate mix	Bananas
			Days	Pounds	Pounds	Pounds	Pounds	Pounds
1	None	3	119	63	202	1.17	293	413
2	Cow manure	3	119	62	199	1.14	307	432
3	APF	3	105	61	202	1.34*	271	371
4	None	4	175	27	193	.91	310	432
5	Cow manure	5	175	28	168	.80	313	431
6	APF	5	175	28	202	.99*	259	360

* Statistically significant differences at 5-percent level from lots No. 1 and No. 4, respectively.

As may be observed in table 2, the lots fed the APF concentrate made slightly faster daily gains and utilized the feed more efficiently. The addition of cow manure to the ration apparently had little effect and did not increase the rate of growth of the pigs or the efficiency of feed utilization over the control lots. Further, in lot No. 5, which was fed cow manure, there was a slight depression of growth as compared with the control lot No. 4.

Discussion

Owing to irregular feed supplies and the scarcity of vitamin and animal protein concentrates, rations must be simplified in American tropical areas.

The results of experiment No. 1 indicate that corozo palm nut and sesame oil meals may be fed separately or in combination with similar results. These oil meals did not exercise a mutual supplementary effect at the levels fed in this trial. Squibb and Wyld, 1949, have shown

that sesame oil meal likewise had no supplementary effect on corozo oil meals when fed to rats. The rate of gain and the efficiency of feed utilization observed in this experiment may be considered satisfactory for pigs fed these simplified all-vegetable low protein rations.

In experiment No. 2, the bananas were allowed to ripen and were fed with the skins. Since bananas are a carbohydrate feedstuff, they had to be fed with a high protein concentrate mixture. By feeding the concentrate mix in a ratio to the ripe bananas, the intake of crude protein was regulated to the weight of the pigs.

The addition of the APF concentrate in lots Nos. 3 and 6 increased the rate of gains and the efficiency of feed utilization over those of the control lots Nos. 1 and 4. The increased gains, however, were not so large as those previously reported (Cunha *et al.*, 1949; Lepley *et al.*, 1949). This difference may have been caused by the presence of some APF in the control ration and/or a lower APF-potency intake. An assay at the end of the trial of the APF concentrate, which was kept in the laboratory at 20° C. to 24° C., indicated some loss of the original potency.

Although the dried cow manure supplied the same APF potency as the APF concentrate, the pigs did not benefit from it. The lots fed the cow manure were unthrifty and lacked uniformity. The tendency of the cow manure to depress the rate of growth of the pigs in lot No. 5 may have been because these pigs were younger at the beginning of the trials than those of lot No. 2. The apparent failure of pigs to utilize the APF potency of the cow manure was not caused by small total feed intake or unpalatability of the rations. The pigs fed cow manure ate the rations readily and consumed as much feed as did the other lots.

In none of the experiments reported herein were there clinical symptoms of malnutrition in any of the pigs. Although the experimental conditions were not the same, the growth rates and efficiency of feed utilization of the pigs compared favorably to those reported by Henke, 1949, at the Hawaiian Experiment Station. These preliminary data are encouraging as they indicate that Duroc Jersey pigs fed simplified all-vegetable protein rations will do well in this tropical area.

Summary

Corozo palm nut and sesame oil meals may be fed separately or in combination to growing and fattening pigs with similar results. These meals did not exercise a mutual supplementary effect at the levels fed in these studies.

Ripe bananas produced satisfactory gains when fed in 1:1 and 2:1 ratio with a high protein concentrate mixture.

An APF concentrate increased the rate of gain and the efficiency of feed utilization over those of the control lots.

Under the conditions of these experiments, cow manure fed to provide the same APF potency as an APF concentrate did not increase the rate of gain or the efficiency of feed utilization over those of the control lots.

The rate of gain and efficiency of feed utilization for growing and fattening pigs fed simplified all-vegetable protein rations with and without the APF in this tropical area were satisfactory and comparable to those expected in temperate zones.

Literature Cited

Annual Report, 1948–1949, Instituto Agropecuario Nacional, Guatemala, C.A.

Bogert, J. L. 1942. Dietary uses of the banana in health and disease. Res. Dept. United Fruit Co., New York, N. Y. 67 pp.

Cunha, T. J., J. E. Burnside, H. H. Hopper, A. M. Pearson and R. S. Glasscock. 1949. Effect of animal protein factor supplement, B_{12} methionine and soil on corn rations supplemented with peanut, soybean and fish meals. JOURNAL OF ANIMAL SCIENCE 8:616. (Abst.)

Henke, L. A. 1949. Swine feeding trials in Hawaii. Univ. Hawaii Agr. Expt. Sta. Bul. No. 99.

Lepley. K. C., D. V. Catron, and C. C. Culbertson. 1949. Comparison of different sources of animal protein factor for growing-fattening pigs. JOURNAL OF ANIMAL SCIENCE 8:625.

Lewy van Severen, M., and R. Carbonell. 1949. Estudios Sobre Digestibilidad de la Pulpa de Café y de la Hoja de Banano. El Café de El Salvador 19:1619.

Munsell, H. E., L. O. Williams. L. P. Guild, C. B. Troescher, G. Nightingale, and R. S. Harris. 1949. Composition of food plants of Central America, I. Honduras, Food Res. 14:1.

Squibb, R. L., A. Falla, J. A. Fuentes. and H. T. Love. 1949. Value of desmodium, pigeonpea fodder, and Guatemalan and United States alfalfa meals in rations for baby chicks. Jour. Poul. Sci. 29:482.

Squibb, R. L., and M. K. Wyld, 1949, Trimestral report of the animal husbandry department of the Instituto Agropecuario Nacional, Guatemala.

RELATIVE VALUE OF VITAMIN A AND CAROTENE FOR SUPPLYING THE VITAMIN A REQUIREMENTS OF SWINE DURING GESTATION AND BEGINNING LACTATION[1, 2]

D. B. PARRISH, C. E. AUBEL, J. S. HUGHES and J. D. WHEAT[3]
Kansas Agricultural Experiment Station

THE National Research Council's (1944) daily vitamin A allowances for pregnant gilts and sows are 13,000 I.U. vitamin A or 20 mg. carotene. Thus, based on the factor of 1.6 as the approximate conversion of crystalline carotene to vitamin A, the allowance for this provitamin is 2.5 times that for preformed vitamin A. Allowances in the foregoing ratio are in harmony with results of earlier vitamin A studies of mammalian species (Guilbert, Howell and Hart, 1940). It was recognized, however, that the allowances for gilts and sows were based upon a limited amount of data, mostly that on growing pigs; therefore it seemed desirable to obtain further information on the relative values of vitamin A and carotene for supplying the vitamin A needs of swine during gestation and early lactation. Data from an investigation of this problem are reported herein.

Experimental Procedures

Two trials were conducted using 15 different Duroc gilts each time. The experimental subjects were removed from pasture in the Fall and placed in dry lot for 3 to 4 weeks, after which time they were divided into three lots and the feeding of experimental diets was begun. The gilts were bred about one month later, at which time they weighed approximately 300 lbs. Animals in lot I, the check lot, were housed together and were fed tankage, yellow corn, salt, and alfalfa hay[4] *ad libitum*.

Animals in lots II and III were housed in individual pens consisting of shelter in a barn and a paved outside lot. Wood shavings were

[1] Contribution No. 434, Department of Chemistry, No. 176, Department of Animal Husbandry and No. 118, Department of Veterinary Medicine.

[2] We are indebted to Distillation Products Inc. for supplying distilled vitamin A concentrates and to American Chlorophyll Inc. for supplying a crystalline carotene preparation used in trial 1. We also wish to acknowledge the R. P. Scherer Corp., Gelatin Products Division, for the generous supply of capsules containing the vitamin A and carotene supplements used in trial 2.

[3] The authors wish to acknowledge the excellent cooperation of Mr. Claude Dunn in assisting with the feeding and management of the experimental animals.

[4] Hay used in trial 1 contained 7.5 mg. carotene/100 g. at the close of the trial; that in trial 2, 14.7 mg.

used as bedding. The basal ration for lots II and III was of the following percentage composition: ground white corn, 81.5; solvent extracted soybean oil meal, 14; brewer's yeast, 1.5; skim milk powder, 2.5; iodized salt, 0.16; bone meal, 0.16; calcium carbonate, 0.16; and vitamin D. The amount of ration fed was adjusted to the weight and condition of the gilt, according to normal practices.

Vitamin A was given to gilts in lot II and carotene to those in lot III at a level of 6500 I.U. daily in trial 1 and 7100 I.U. daily in trial 2. The amounts of supplement given were selected so that animals receiving carotene would get it near marginal levels. Under these conditions it was believed any differences in performance would show up.

During trial 1, the vitamin supplements, crystalline carotene and distilled vitamin A concentrate, were dissolved in corn oil and premixed with soybean meal so that a measure of 20 g. supplied the daily allotment. The supplements were prepared at monthly intervals and stored in the dark at −12° C. A fresh supply for feeding was removed from storage and taken to the barn each week. In trial 2, small capsules containing the daily allotment of the vitamin in corn oil were used. The contents of one of these capsules were mixed with the ration of each individual gilt once daily.

Samples of blood were taken from each gilt at the time of farrowing, and from many of them additional samples were taken at other times during the trial. Blood was centrifuged to obtain serum, which was stored at 4° C. until analyses could be made, usually within two days. Colostrum was obtained by milking 2 to 6 teats as completely as possible while the gilt was farrowing. Pitocin was used to induce colostrum let-down (Ely and Petersen, 1941) in a few cases, but it seemed to be of little help, possibly because the gilts were in labor and their systems already under the influence of this hormone. One pig of each litter was sacrificed before it had consumed colostrum, and another was sacrificed 4 days later for obtaining blood and liver samples. Blood from the newborn pigs was treated in the same manner as that of the gilts; livers were frozen until analyzed, always within 10 days.

The Kimble (1939) method for determining vitamin A in blood serum was used, since similar results were obtained on swine blood serum regardless of whether or not the samples were saponified in the procedure (Parrish *et al.*, 1948). Vitamin A was determined in colostrum by the modified procedure used by Parrish *et al.* (1949), except that 10 ml. of sample was saponified by heating. Livers, trimmed

of connective tissue and large blood vessels, were homogenized in a Waring blendor; a 10-g. sample was saponified, extracted and analyzed in a manner similar to that for colostrum.

Criteria used for estimating the relative values of vitamin A and carotene for gestation and early lactation were: concentration of vitamin A in blood serum and in colostrum of gilts, concentration of vitamin A in blood serum and in livers of new-born and of 4-day-old pigs and condition of gilts and baby pigs.

Results

Results obtained in trial 2 indicated that feeding gilts the carotene supplement for one month caused only relatively small declines in the original serum vitamin A levels. However, after this supplement was given for three months the vitamin A levels in the serum were only 13.8 μg. per 100 ml., which was about six-tenths of that contained in the serum of gilts of the other two dietary groups.

The average vitamin A concentrations (table 1) in serum and in colostrum of gilts at the time of farrowing and in serum and livers of baby pigs usually were smaller in animals of vitamin A supplemented groups (lot II) than in those of check groups (lot I). Differences are significant, however, only for vitamin A levels in livers of the 4-day-old pigs of trial 2. Thus, as judged by the criteria selected, the overall value of vitamin A at levels of 6500 or 7100 I.U. daily was similar to that of natural sources of vitamin A as supplied by the check ration. Gilts in both lots I and II appeared to be in a satisfactory condition and averaged, respectively, 9.1 and 8.2 pigs per farrowing.

Colostrum from dams receiving carotene (lot III) contained only one-half to three-fourths as much vitamin A as did colostrum from dams of the other two lots. Blood serum vitamin A concentrations of gilts receiving carotene were only about one-half of those of gilts receiving either the vitamin A or the check ration. Furthermore, vitamin A concentrations in serum of new-born and of 4-day-old pigs from dams receiving carotene also were approximately one-half of those of pigs from dams in lots I and II, and vitamin A content of livers of pigs from carotene-supplemented dams was markedly lower than that of livers of pigs from dams in the other two dietary groups.

Gilts receiving the carotene supplement appeared normal at farrowing time, but in each trial one animal failed to show pigs. However, parturient dams of this lot farrowed an average of 9.8 healthy pigs, more pigs than dams of either of the other two lots. Three of the four

TABLE 1. CONCENTRATIONS OF VITAMIN A IN BLOOD SERUM AND COLOSTRUM OF GILTS AT TIME OF FARROWING AND IN BLOOD SERUM AND LIVERS OF NEWBORN AND OF 4-DAY-OLD PIGS

Trial	1			2		
Lot[1]	I	II	III	I	II	III
Ration Supplement	Check	Vitamin A	Carotene	Check	Vitamin A	Carotene
Vitamin A in gilt's blood serum, μg./100 ml.	17.7 ±1.28[2]	20.0 ±2.39	10.3 ±3.39	19.2 ±1.63	16.2 ±0.85	7.2 ±1.25
Vitamin A in colostrum, μg./100 ml.	221 ±14.8	191 ±14.6	103 ±18.1	162 ±19.0	196 ±21.4	123 ±27.4
Vitamin A in new-born pig's blood serum, μg./100 ml.	12.5 ±0.75	11.9 ±0.83	6.7 ±2.93	13.7 ±0.64	12.6 ±0.72	5.1 ±0.97
Vitamin A in 4-day-old pig's blood serum, μg./100 ml.	33.4 ±2.97	30.5 ±2.99	17.7 ±4.69	36.4 ±2.46	26.0[3] ±5.62	14.5 ±4.31
Vitamin A in new-born pig's liver, μg./g.	10.7 ±1.13	6.8 ±1.96	1.6 ±1.20	10.8 ±1.41	8.9 ±2.39	1.1 ±0.61
μg./liver	373 ±25.5	211 ±56.4	45 ±30.7	363 ±53.4	288 ±68.3	14.9 ±4.30
Vitamin A in 4-day-old pig's liver, μg./g.	18.9 ±2.44	18.3 ±4.50	3.8 ±2.3	20.9 ±1.64	14.7[3] ±1.48	3.9 ±1.28
μg./liver	821 ±116	808 ±182.6	163 ±31.5	798 ±150	594[3] ±20.1	189 ±80.6

[1] Five animals per lot, except in each trial Lot III contained only 4 animals by farrowing time.
[2] Standard error.
[3] One gilt refused to care for her pigs; only 4 pigs available at this stage.

baby pigs that died with scours during trial 2 were from dams in lot III (carotene supplemented), but the infection was general in the area and probably was not related to the experimental treatment. In spite of the fact one gilt of lot III was slow coming into milk and three of her pigs were lost, apparently from starvation, slightly more pigs were raised per dam of lot III than by those of lot II.

Analyses of serum of 8 gilts (all three lots of animals used in trial 2 being represented) during terminal stages of gestation and early stages of lactation revealed that in all animals the vitamin A concentrations were smallest at the time of farrowing. The average changes[5] were 177, 154, 132, 100, 159 and 162 on, respectively, the 18th, 6th and 2nd days ante partum and the 0, 2nd and 4th days post partum. Vitamin A concentrations in the serum of gilts of lots I and II, trial 2, on the 4th day post partum were nearly the same as 16 to 22 days ante partum (27.6 μg. and 25.1 μg., respectively, post partum and 28.6 μg. and 24.2 μg., respectively, ante partum). In contrast, vitamin A concentrations in serum of animals of lot III were only 9.3 μg and 15.0 μg at the two respective periods.

When results from the two trials were pooled, a correlation of 0.60 was found for vitamin A in blood serum of gilts at the time of farrowing and in their colostrum. A correlation of 0.83 was found for vitamin A in blood serum of gilts and in that of their new-born pigs. The correlation of vitamin A concentration in serum of gilts and in liver of new-born pigs was 0.56, only a slightly larger value (0.58) being found when level in serum and total content per liver were compared. The correlation of vitamin A in blood serum and in liver of new-born pigs was 0.67. Correlation of vitamin A at birth and at 4 days of age in pig's blood serum was 0.55 and in pig's liver was 0.70.

Discussion

At the time of parturition the vitamin A concentration in serum and in colostrum of gilts of both lots I and II were essentially as large as, or larger than, those previously reported for sows and gilts fed typical herd feeds (Bowland *et al.*, 1949; Braude *et al.*, 1945–46; Eaton *et al.*, 1949; Leucke *et al.*, 1947; Thomas *et al.*, 1947; and Whiting *et al.*, 1949). Some of the higher values observed in the present study possibly are due to the fact that only gilts were used, for if swine respond similarly to cattle (Parrish *et al.*, 1949), it would be expected that vitamin A concentrations would be higher in colostrum

[5] Some data had to be adjusted (Latschar *et al.*, 1949) before they could be summarized. Values are compared to a base value of 100 which represents the vitamin A level of the blood sample taken at time of farrowing.

of gilts than in that of older sows. Blood serum and liver vitamin A concentrations of new-born pigs from gilts in lots I and II likewise were as large as, or larger than, those reported by Eaton *et al.* (1949), Thomas *et al.* (1947), and Whiting *et al.* (1949) for pigs from dams fed normal feeds.

Although vitamin A levels in colostrum of gilts receiving only 6500 or 7100 I.U. of vitamin A daily as carotene (lot III) and in serum of their new-born pigs were lower than values on colostrum and serum of pigs from the other two lots, they were not markedly lower than reported for animals receiving normal feeds by the authors previously cited. The carotene supplement fed the dam, however, was adequate for only about one-fourth as much liver storage of vitamin A in new-born pigs, as in new-born pigs of the check lot or of those from dams receiving typical swine rations, as reported by the aforementioned authors.

It is interesting that blood and liver stores of vitamin A in new-born pigs from gilts receiving carotene (lot III) were as large as, or larger than, those reported for new-born calves, kids or lambs from dams fed normal rations (Moore and Berry, 1944; Parrish *et al.*, 1946–47; Pope *et al.*, 1949; Spielman *et al.*, 1949; Thomas *et al.*, 1947; Whiting *et al.*, 1949; Wise *et al.*, 1946; Wise *et al.*, 1948). After colostrum and milk were consumed for the first four postnatal days, the increases of vitamin A in blood serum and in livers of the pigs of gilts receiving the carotene supplement were comparable to findings on new-born calves whose dams received normal rations.

The declines in vitamin A levels in serum of gilts during the late stages of gestation and the increases following parturition are similar to observations on tocopherols (Latschar *et al.*, 1949) and on vitamin A and carotenoids (Kuhlman and Gallup, 1944; Sutton *et al.*, 1945; Wise *et al.*, 1947) in serum of cattle. In swine, however, the minimum values appeared to have occurred nearer to the time of parturition than observed in cattle.

Approximately 7000 I.U. of preformed vitamin A daily seemed to be adequate for pregnant gilts, as judged by concentrations of vitamin A in their blood serum and in their colostrum, by their general health and ability to recover to normal serum vitamin A levels after farrowing, and by concentrations of vitamin A in blood serum and livers of new-born and 4-day-old pigs. The requirement probably is increased if vitamin A intake of the dam before pregnancy is inadequate. Based on these same criteria, 7000 I.U. of carotene daily were not as effective as preformed vitamin A, particularly for liver storage in the baby

pigs. There was no positive evidence, however, that gilts in the carotene group (lot III) or their pigs suffered from a deficiency of vitamin A. Results with gilts tend to substantiate previous findings with growing pigs (Guilbert *et al.*, 1937) that the requirements of swine for carotene are higher than for vitamin A.

Summary

In two different trials a comparison was made of the relative values of vitamin A and carotene, when added to a low-carotenoid basal diet at levels of 6500 or 7100 I.U. daily, for supplying the vitamin A for gilts during gestation and early lactation. Results on these animals also were compared with those on gilts of a check lot that received a typical herd ration. Criteria for estimating the relative values of vitamin A and carotene were: concentration of vitamin A in blood serum and in colostrum of gilts, concentration of vitamin A in blood serum and in livers of new-born and of 4-day-old pigs, and condition of gilts and baby pigs.

Vitamin A concentrations in blood serum of vitamin A supplemented gilts at parturition, in their colostrum and in serum and livers of their new-born and 4-day-old pigs, were essentially the same as vitamin A concentrations in similar materials from animals of the check lot, the values being significantly lower only for vitamin A in livers of 4-day-old pigs from dams of the vitamin A dietary group in one trial.

Vitamin A concentrations in colostrum of gilts receiving crystalline carotene were only one-half to three-fourths of those in colostrum from dams of the other dietary groups. Concentrations of vitamin A in blood serum of carotene-supplemented dams at the time of parturition and in serum of their new-born and 4-day-old pigs were approximately one-half of those of animals of the vitamin A and the check lots. Concentrations of vitamin A in livers of new-born and 4-day-old pigs from carotene-supplemented dams were less than one-fourth of those in livers of similar pigs from dams of the other two lots. Although there was no positive evidence that the carotene-supplemented gilts or their pigs suffered from a vitamin A deficiency, the data clearly shows that unit for unit carotene is less effective than preformed vitamin A as a vitamin A supplement for swine during gestation and early lactation.

Vitamin A concentrations in blood serum of the dams decreased as parturition approached and increased during the days immediately following parturition.

Literature Cited

Bowland, J. P., R. H. Grummer, P. H. Phillips and G. Bohstedt, 1949. The vitamin A and vitamin C content of sows' colostrum and milk. JOURNAL OF ANIMAL SCIENCE 8:98.

Braude, R., S. K. Kon and S. Y. Thompson. 1945–46. A note on certain vitamins of sows' colostrum. Jour. Dairy Res. 14:414.

Eaton, H. D., J. A. Christian, F. C. Daugherty, A. A. Spielman and L. D. Matterson. 1949. The effect of crude soybean lecithin on the absorption and utilization of vitamin A fed prepartum to the ewe and sow. JOURNAL OF ANIMAL SCIENCE 8:224.

Ely, F.. and W. E. Petersen. 1941. Factors involved in the ejection of milk. Jour. Dairy Sci. 24:211.

Guilbert, H. R., C. E. Howell and G. H. Hart. 1940. Minimum vitamin A and carotene requirements of mammalian species. Jour. Nutr. 19:91.

Guilbert, H. R., R. F. Miller and E. H. Hughes. 1937. The minimum vitamin A and carotene requirement of cattle, sheep and swine. Jour. Nutr. 13:543.

Kimble, M. S. 1939. The photoelectric determination of vitamin A and carotene in human plasma. Jour. Lab. Clin. Med. 24:1055.

Kuhlman, A. H., and W. D. Gallup. 1944. Changes in blood-plasma carotene associated with parturition and lactation of Jersey cows. Jour. Dairy Sci. 27:633.

Latschar, C. E., G. H. Wise, D. B. Parrish and J. S. Hughes. 1949. Concentrations of various constituents in blood of dairy cows during stages of terminal gestation and initial lactation. I. Effect of prepartal diet on serum tocopherols. Jour. Nutr. 38:503.

Luecke, R. W., C. W. Duncan and R. E. Ely. 1947. Milk studies. I. Some vitamins and trace elements found in the colostrum of the dairy cow, beef cow and swine. Arch. Biochem. 13:277.

Moore, L. A. and M. H. Berry. 1944. Effect of colostrum on the vitamin A and carotene content of blood plasma of new-born calves. Jour. Dairy Sci. 27:867.

National Research Council. 1944. Recommended nutrient allowances for swine. No. 2:1.

Parrish, D. B., G. H. Wise, F. W. Atkeson and J. S. Hughes. 1949. Properties of the colostrum of the dairy cow. III. Several factors affecting vitamin A and carotenoid content. Jour. Dairy Sci. 32:209.

Parrish. D. B., G. H. Wise and M. J. Caldwell. 1946–47. Unpublished.

Parrish, D. B., G. H. Wise and J. S. Hughes. 1948. Vitamin A and carotenoids in the blood serum of dairy cattle. Chemical methods for determination. Anal. Chem. 20:230.

Pope, A. L., P. H. Phillips, and G. Bohstedt. 1949. Vitamins A and C concentrations in the blood plasma of ewes, their milk, and in the blood plasma of their lambs. JOURNAL OF ANIMAL SCIENCE 8:58.

Spielman, A. A., H. D. Eaton, J. K. Loosli and K. L. Turk. 1949. The effect of prepartum vitamin A supplementation on the health and performance of the young calf. Jour. Dairy Sci. 32:367.

Sutton, T. S., H. E. Kaeser and P. A. Soldner. 1945. Changes in the level of vitamin A and carotene in the blood plasma of dairy cows associated with parturition and beginning lactation. Jour. Dairy Sci. 28:933.

Thomas, J. W., J. K. Loosli and J. P. William. 1947. Placental and mammary transfer of vitamin A in swine and goats as affected by the prepartum diet. JOURNAL OF ANIMAL SCIENCE 6:141.

Whiting, F., J. K. Loosli and J. P. Willman. 1949. The influence of tocopherols

upon the mammary and placental transfer of vitamin A in sheep, goat and pig. JOURNAL OF ANIMAL SCIENCE 8:35.

Wise, G. H., F. W. Atkeson, M. J. Caldwell, D. B. Parrish and J. S. Hughes. 1947. Effects of high vitamin A intake on milk and fat yields and on vitamin A constituents in milk, blood, and livers of dairy cows. Jour. Dairy Sci. 30:279.

Wise, G. H., M. J. Caldwell and J. S. Hughes. 1946. The effect of the prepartum diet of the cow on the vitamin A reserves of her newborn offspring. Science 103:616.

Wise, G. H., M. J. Caldwell, D. B. Parrish, F. W. Atkeson and J. S. Hughes. 1948. Relation of typical postnatal changes in the diet of the dairy calf to the concentration of carotenoids and vitamin A in the blood serum. JOURNAL OF ANIMAL SCIENCE 7:70.

NEWS AND NOTES

May, 1951 issue of the JOURNAL OF ANIMAL SCIENCE

The forty-third annual meeting of the American Society of Animal Production will be held in the Hotel Sherman in Chicago, Illinois, on November 23 and 24, 1951, with a dinner for the honored guest on November 26. Members planning to present papers are reminded that titles must be in the hands of the secretary, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., by July 20, following which abstracts must be filed with him by August 15.

Nominations for the Morrison Award, in writing, are due in the Secretary's Office by June 15. All members of the Society except members of the Executive Committee and the Award Committee are eligible to make one nomination. The rules are the same as last year and are essentially the same as published in the JOURNAL OF ANIMAL SCIENCE, Vol. 5, pp. 236–237, 1946. All nominations must be accompanied by a brief biography of the nominee and a list, together with copies, of publications concerning the research, and a statement of the importance to the livestock industry of the work upon which the nomination is based.

Nominations for American Feed Manufacturers Award should be sent to the Secretary's Office by June 15. Research published in 1949 and 1950 will be considered for the 1951 award. The rules governing this award are unchanged from last year and are stated in the JOURNAL OF ANIMAL SCIENCE, Vol. 7, pp. 257–258, 1948.

Professor G. Bohstedt, Chairman of the Department of Animal Husbandry, University of Wisconsin, has been chosen as the honor guest for the American Society of Animal Production at its meeting November 23 and 24, 1951. Professor Bohstedt's portrait will be presented to the Saddle and Sirloin Club at the time of the banquet in his honor on November 26. Professor J. G. Fuller of the Animal Husbandry Department, University of Wisconsin, is chairman of the committee in charge of arrangements for the event.

The Western Section of the American Society of Animal Production will meet at Montana state college, Bozeman, on July 9 and 10, 1951.

The committee on Ralston-Purina Fellowship Awards has selected the winners for the school year 1951–52. The principals named for Animal Husbandry were Raymond F. Sewell of Florida, James M. Fransen of Oklahoma, and Daniel W. Beardsley of Florida. The institutions at which these men preferred to work were Cornell, Purdue, and Illinois respectively. Arthur R. Schulz of Colorado was named as first alternate, Duane E. Ullrey of Michigan as second alternate, and Robert G. Eggert of Nebraska as third alternate. The Dairy Husbandry principals were Harold A. Ramsey of Kansas and Henry J. Bearden of Mississippi. These men preferred North Carolina State and Pennsylvania State respectively. George Hyatt, Jr. of West Virginia was named as first alternate and Stanley A. Ellsworth of Maine was named second alternate. The principals for poultry husbandry were Edward C. Naber of Wisconsin and James R. Jowsey of Saskatchewan. The University of Wisconsin and MacDonald college were the institutions at which these men preferred to continue their work. Ernest Williams of Louisiana and Lawrence R. Berg of Washington were named as first and second alternates respectively. The nature of these awards and some of the rules governing them were published in the JOURNAL OF ANIMAL SCIENCE, 1951, Volume 10, page 307.

The XIIth International Congress of Pure and Applied Chemistry will be held in New York City in September 1951 in connection with the 75th Anniversary Meeting of the American Chemical Society. The Section on Food, Nutrition and Agricultural Chemistry will welcome research papers on food, nutrition and agricultural chemistry from all foreign and American research workers who plan to attend the New York meetings. Application blanks and detailed information can be obtained by writing to Dr. Harry L. Fisher, Administrative Assistant, 2101 Constitution Ave., Washington 25, D. C., or to Dr. R. Adams Dutcher, Secretary Section 6, Food and Nutrition, Pennsylvania State College, State College, Pennsylvania.

A publication entitled "Report of the Inter-American Meeting on Livestock Production" has been issued by the Food and Agriculture Organization of the United Nations, Washington, D. C., as FAO Development Paper No. 8. It contains background papers on various aspects of livestock production prepared by R. T. Allman, Douglas H. K. Lee, Ralph W. Phillips, A. O. Rhoad, A. T. Semple and B. T. Simms. In addition it contains the summary of discussions and the conclusions and recommendations of the Inter-American Meeting on Livestock Production which was held in Turrialba, Costa Rica, on 9–20 October, 1950.

The Principles and Practice of Bacteriology, by Bryan and Bryan, has now been published in its fourth edition by Barnes and Noble, New York. An attempt has been made in this book to bring together the important facts, processes and techniques in veterinary, agricultural and industrial bacteriology. Information and techniques developed during World War II as well as recent significant developments with bacteriostatic agents, new antibiotics, etc., are included.

The Care and Breeding of Laboratory Animals, edited by E. J. Farris, was published by John Wiley and Sons, New York in October, 1950. The information contained in this book is based upon the practical experiences of the fifteen different experts selected to write about the different species. Chapters are included on the monkey, rat, mouse, guinea pig, hamster, rabbit, dog, cat, ferret, opossum, domestic fowl, reptiles, amphibia, fishes and drosophila.

L. L. Madsen of the Animal Husbandry Department, Utah Agricultural College has been made president of that college, and James Bennett has been appointed head of the animal husbandry department, succeeding Dr. Madsen.

Jack Kelley, graduate of Kentucky and former North Carolina swine specialist, was promoted on July 1, 1950, as leader of the Animal Husbandry project of the North Carolina College of Agriculture, to succeed L. I. Case, retired.

W. E. Flint, former county agent at large, was made assistant extension animal husbandman, New Mexico Extension Service, effective July 1, 1950.

David S. Weaver has been appointed director of extension service in North Carolina, effective October 1, 1950, to succeed Director Schaub, who retired September 30, 1950.

Alvin P. Parkham, former county agricultural agent, was made assistant extension animal husbandman in Louisiana, September 1, 1950, to succeed Forrest R. McClain, who resigned.

Thomas W. Wickersham, former county extension director and Iowa State graduate, was appointed extension animal husbandman, Iowa State College, October 1, 1950.

R. M. Bethke of Ohio State Experiment Station, became vice president in charge of research and product control of Ralston Purina Company, January 1, 1951.

The Introduction to Agricultural Chemistry by Dutcher, Jensen and Althouse, was published by John Wiley & Sons, Inc., New York, in January, 1951. It follows the general plan outlined in the Dutcher-Haley Introduction to Agricultural

Biochemistry, but has been rather completely revised and rewritten. Several new chapters have been added. These have to do with farm chemurgy, protein metabolism and nutrition and mineral metabolism and nutrition.

The fourth edition of Milk and Milk Products, by Eckles, Combs and Macy was published by McGraw-Hill and Co., New York, in February, 1951. The book has been revised extensively to give a thorough presentation of the latest information on the chemistry and bacteriology of milk, common dairying processes, the manufacture of dairy products, dairy testing and dairy calculations.

Gordon M. Cairns has been named dean of agriculture of the University of Maryland, succeeding Thomas B. Symons, retired. James M. Gwin, formerly in charge of poultry extension in the department of poultry husbandry, has been named director of the agricultural extension service of the University of Maryland.

E. L. Scott, former animal husbandry staff member at the University of Arizona and now a prominent breeder of Herefords, was elected president of the American Hereford Association at the last annual meeting.

W. A. Craft, director of the USDA Regional Swine Breeding Laboratory and Rosalie Rathbone, head of textiles and clothing at Iowa State College, were married in August and are now at home, 2030 Country Club, Ames, Iowa.

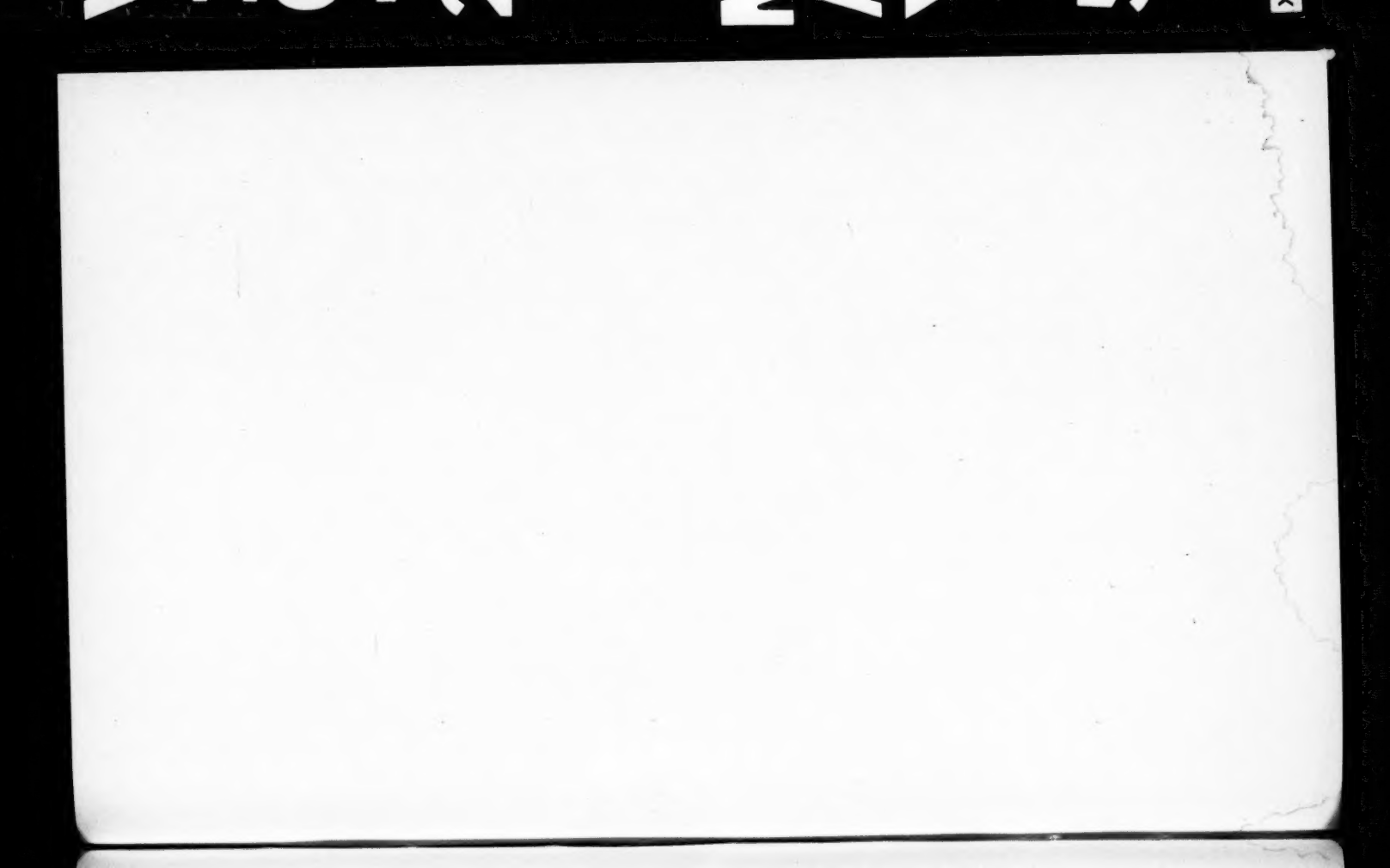
Marvin Koger, animal husbandry staff member, New Mexico, has changed locations and gone to the University of Florida, where he will have charge of work in genetics.

Randall J. Jones became associate dean of agriculture and associate director of the agricultural experiment station at Oklahoma A. & M. College, Stillwater, on January 1, 1951.

E. T. Robbins, long-time extension animal husbandman, University of Illinois, who retired from active duty a few years ago, died in January, 1951.

George Henderson, extension animal husbandman, Utah Agricultural College, was a member of a recent educational tour conducted by a Chicago packer.

R. M. Jordan, of the faculty of the Animal Husbandry Department of South Dakota State College, will return June 1st to Brookings after having spent a year doing graduate work at Kansas State College.



INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, double-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should contain a clear statement of the purpose of the investigation and its relation to other work in the same field, but long reviews should be avoided. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results, or their relation to some problem of the livestock industry. Each paper should end with a brief summary outlining the points proved in the investigation and their application, or their relation to a livestock problem.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. A maximum of eight pages per paper will be published without charge. Over-run in excess of this amount will be charged to the author or his institution at current publication costs. This restriction does not apply to invited review papers. The cost of making engravings, in excess of one page per paper and of printing tables in excess of two pages per paper, will also be charged to the author or his institution.

6. Authors will receive galley proof of articles, together with a reprint order form and a form for supplying an abstract for "Biological Abstracts." Corrected proof, reprint order and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue. Institutional orders for reprints should be made out to the American Society of Animal Production.

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest concerning the members, and other items of interest to the membership. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. L. E. Casida, Department of Genetics, University of Wisconsin, Madison, Wisconsin, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. J. I. Miller, Department of Animal Husbandry, Cornell University, Ithaca, N. Y., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

X